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VOL. 10 MARCH, 1923 No. 2

THE LOAD CURVE OF CONSTRUCTION EQUIPMENT[1]

BY HOMER V. KNOUSE[2]

During the period of the world war and for two years thereafter, the great increase in construction required by the public utilities to meet demands made by industry, and the shortage of skilled and common labor, made imperative the purchase of equipment which would multiply the effectiveness of man power. Designers and builders of this class of machinery recognized the demand and produced equipment to meet the needs of the utility, and only by the co-operation of manufacturer and user was it possible to carry out the tremendous program of those years.

With labor very scarce and quite inefficient, even with the high prices of construction equipment, it was not a difficult problem to justify the investments; but, with the economic curve sloping in a downward direction, the problem to be faced assumes formidable proportions. The depreciation and interest rate applying on war-time purchase prices imposes a unit fixed charge, which, added to the general operating expense, makes costs nearly approach the unit costs under hand methods current before the war. And were it possible to dispose of this equipment, it seems, at times, as though a return to former practices would be the better course.

[1] Presented before the Iowa Section meeting, November 2, 1922.

[2] Construction Engineer, Metropolitan Utilities District, Omaha, Neb.

The solution of the problem is, of course, "intensive operation," or an improvement of the load curve, to the end that the overhead charges may be spread over a larger number of units. It is not the purpose of the writer to claim that this result has been achieved in any considerable degree, but, rather, to present some of the methods that have been considered as a means to that end.

Figure 1 represents the load curve of a wheel type trenching machine having a maximum capacity of a trench 24 inches wide by 6 feet deep, and which is considered to be of the highest type construction in its class. The shaded areas above the line represent lengths of trench excavated, and the shaded areas below show, in hours, the time the machine was out for repairs, inspection and general oiling. The white areas represent, in hours, the time of moving from job to job. It should be stated, however, that the machine should not be penalized as fully as this curve would indicate, for it is undoubtedly true that the total amount excavated might have been increased had it been possible for the pipelaying gang to keep up. This was noticeable where short lines were laid, inasmuch as the time required for the connection was great in proportion to the time for the laying of straight pipe. The result was that the operator would spend time repairing or overhauling, which might as well have been devoted to digging had there been work to do.

In figure 2 are presented three curves giving the performance of the machine by weeks. The first curve, or "machine operator's score" gives values of hours digging plus hours moving divided by hours digging plus hours moving plus hours repairing. Idle time is not considered in this curve, inasmuch as the operator is not responsible for the time when there is no work provided for the machine.

The second curve or "general foreman's score," checks the total time of digging, moving and repairing to total working hours, and is an index of the degree to which work was provided for the machine.

The third curve is a combination of the first two, and represents the value of the machine to the District.

By decreasing repair time and increasing digging time, it will be possible for the operator to increase his score. Since digging time is figured by measuring the amount of trench opened and dividing by an allowance of 100 feet per hour, it is not unreasonable to expect that a score of between 90 and 100 may be obtained by the operator. While the machine is capable of digging 138 feet per hour, an allowance for "digging in," raising over other services, cleaning of buckets

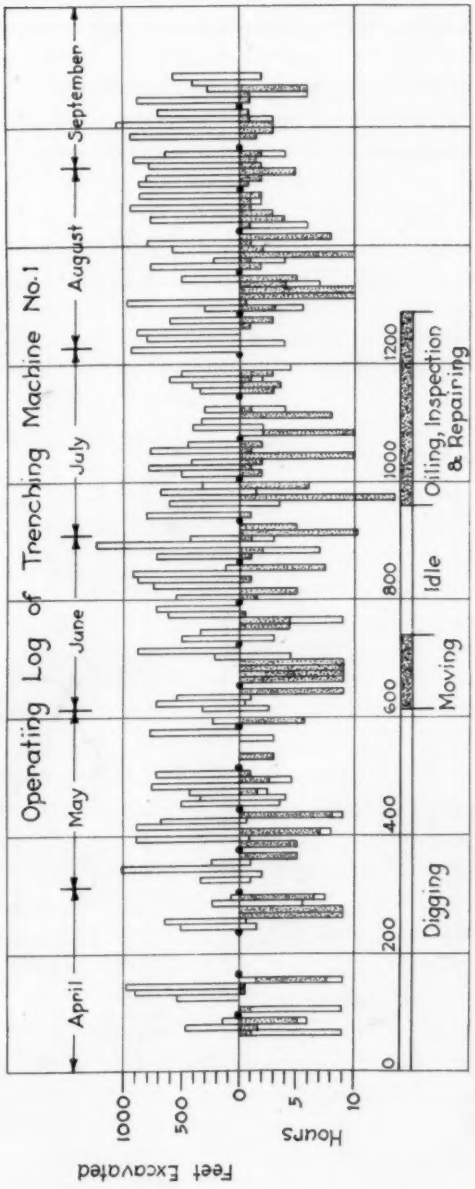
Operating Log of Trenching Machine No.1
April
May
June
July
August
September
Feet Excavated
1000
500
0
Hours
10
5
0
200
400
600
800
1000
1200
Digging
Moving
Idle
Oiling, Inspection & Repairing

FIG. 1

when necessary, oiling, greasing and adjustments, makes 100 feet per hour for the entire day a reasonable average to expect.

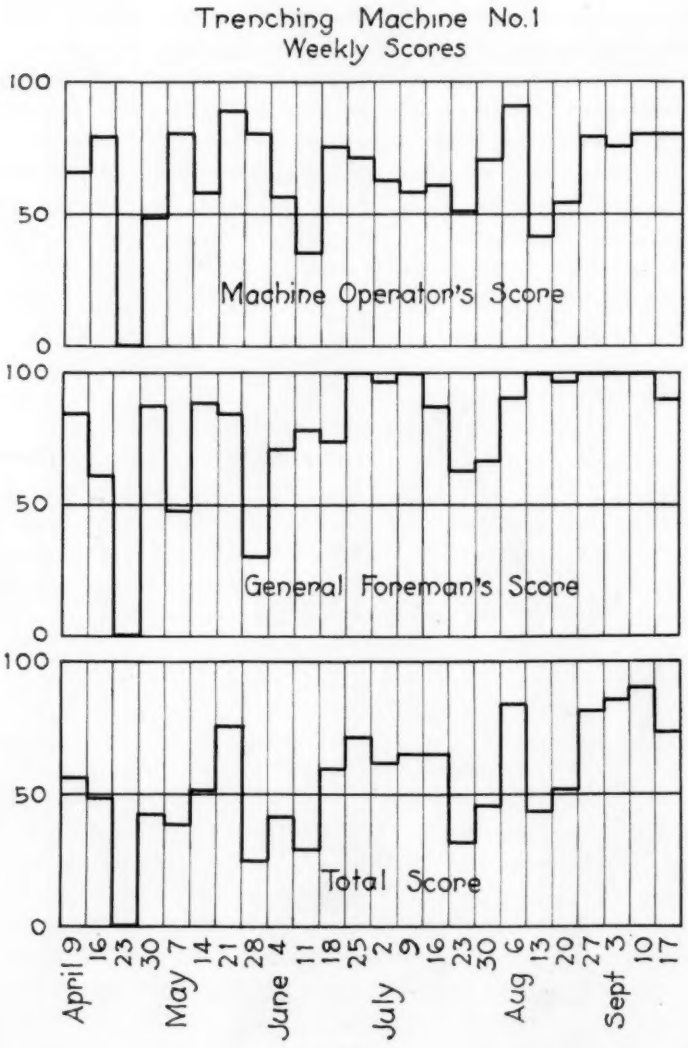

FIG. 2

The general foreman will be able, by better coördination of his work, to reduce the idle time and to obtain a higher score. Pipe

laying gangs can be directed to follow the machine as may be necessary to keep their part of the work as closely behind the trenching machine as possible, and when numerous or difficult connections are necessary, extra gangs may advantageously be used to keep the progress at a maximum.

It is proposed to furnish a corrected score sheet weekly to the men interested, and to instruct them so that they may figure their score day by day and thus be fully informed as to how they are succeeding in obtaining maximum results. While this should result in obtaining a better load curve for the machine it should also result in increasing the efficiency of all correlated work.

It is confidently expected that, by using the system of records, the men responsible for the various factors will be able to visualize the progress of their work and so increase the operating efficiency that the unit cost of trenching may be decreased from 20 to 30 per cent.

The machine considered in the foregoing paragraphs is essentially a one-purpose machine; but, in the construction department of utilities, there are many operations which, although rather dissimilar, may often be performed by a single piece of equipment. For example, a back-filler now in use by this department has had its load curve greatly benefited by adapting it to several uses. In addition to being a rapid back-filler, it has been used on other work, as follows:

For unloading cast iron pipe from cars, the costs were reduced 60 per cent (fig. 3).

With bottom dump buckets, deep excavations may be handled more cheaply and the work speeded up as compared with hand methods.

For erecting reinforcing steel and forms in building work, the back-filler made a satisfactory traveling crane.

For pouring concrete in column forms, a special mast and bucket made the handling of the work a simple matter (fig. 4).

The Metropolitan Utilities District has in service a small gasolene-driven drag line which has proven very useful for excavating trenches for large size pipe, for handling pipe while laying, for unloading sand and stone, for unloading and bunkering coal and as a back-filler.

An Ingersoll-Rand air compressor was placed in service about July 1st. While cost data are not available in sufficient detail to be published, it is felt that its purchase was wise.

The compressor was delivered on a steel truck, but it soon became evident that the racking due to trailing behind a truck, over rough pavements, would cause material damage. It was then decided to mount the unit on the chassis of an old truck which had been retired from service, and the first plan contemplated the use of the chassis as a trailer. As the mounting progressed, it became evident that, with only minor changes, the unit might be made to be propelled by the engine of the compressor, and in figure 5 the completed unit is shown. The space formerly occupied by the engine has been utilized as a tool-box, and all necessary equipment may be carried to

FIG. 3

handle the various classes of work, without the necessity of providing a truck to aid in moving from job to job.

The compressor has been used in connection with a "paving breaker," to cut paving for the installation of water and gas mains. This paving breaker is a heavy, non-rotating air hammer, using $1\frac{1}{2}$ inches moil point steel, and is very effective in breaking concrete base. A chisel point tool is used for cutting and lifting sheet asphalt, or asphaltic concrete, and the moil point is used for raising brick (fig. 6).

Foundry tampers, to which was added a large foot, were found effective in tamping re-filled material in trenches. One man with this tool was able to do the work of six men with hand tampers and

do it better. Where the soil was dry and powdery, it was necessary to moisten the material in order to get it all into the trench.

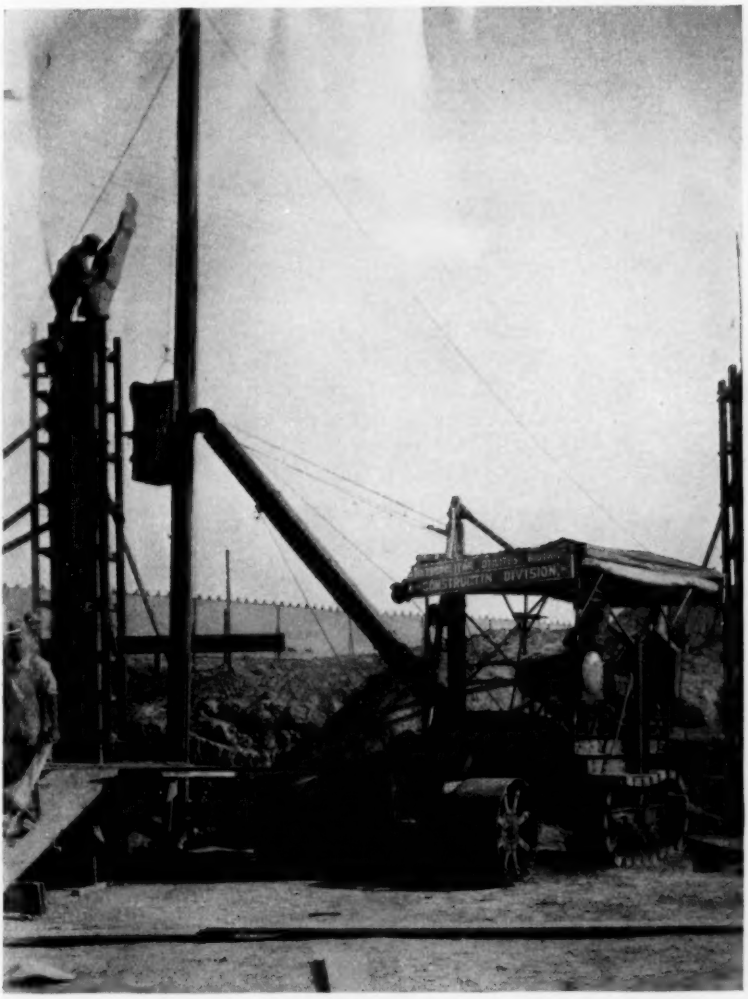

FIG. 4

A jackhammer drill, for use in cutting holes in walls and slabs, and for removal of old foundations, is a valuable addition to the equipment, and chipping hammers are useful in many places.

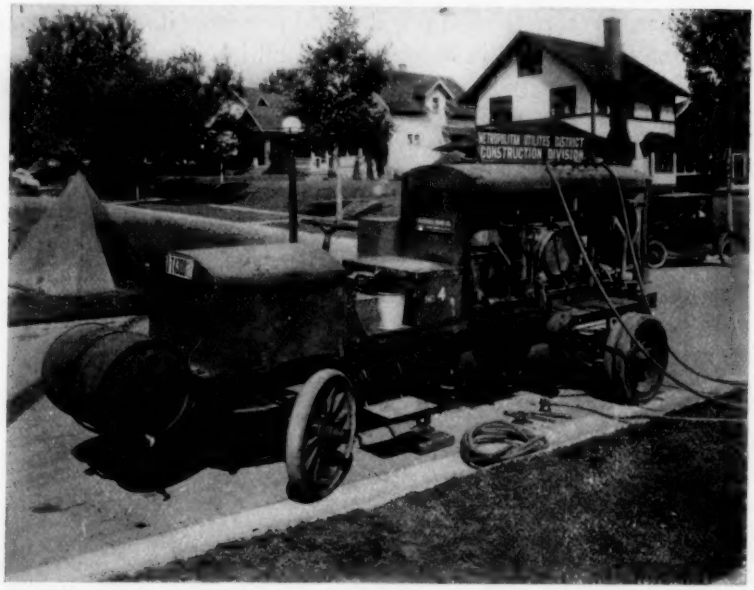

FIG. 5

FIG. 6

A cement gun has been used on two jobs, one of which was especially difficult, due to the desire to obtain a pleasing architectural effect on concrete walls adjacent to pressed brick and cut stone work. As far as appearance is concerned, the work was entirely successful, and it is believed that the stucco will remain permanently in place. Another job was the guniting of the vertical walls of a settling basin, and the compressor has proven satisfactory for the use of the cement gun, as well as for running the chipping hammers and for sand blasting.

When used in connection with a cement gun, a large field of use is opened to the compressor, since gunite cannot only be used for improving the appearance of old structures, but is particularly adapted to the water-proofing of structures designed to be water containers. Undoubtedly many more uses will be found for the compressor as particular conditions arise and it should be possible to get an attractive load curve.

In a period of less than a decade, the urban transport system has been completely revolutionized, the horse-drawn vehicle having almost entirely given way to the automobile, and, while it would not seem to us possible to carry on our business today with the former equipment, the writer feels that there is great waste in the utilization of automobile equipment. A great deal of care should be given to the selection of trucks, to obtain economical capacities, body types suited to the work, tire equipment which has a low cost per mile and yet of a design which may successfully travel under difficult road conditions, under the emergency requirements so often imposed in water works operation. But, with all these conditions ideal, considerable losses may occur due to a lack of consideration of its proper utilization. The writer uses a despatcher to order the movements of all trucks, and has found that not only was there less idle time, but material was delivered to the job more nearly at the time it was needed, gangs could be moved at the time they were ready and a truck was always available at some point in the city to handle emergencies. In this connection, the trailer was designed to make rapid transit of repair tools possible without the necessity of loading and unloading a truck whenever a move was necessary. Since this item of labor was avoided, it was possible to equip the trailer with tools to meet practically all emergencies and make it a much more valuable unit than under the previous plan of loading small tool boxes, derricks, tackle and shovels onto a truck. By the use

of a spring-cushioned, rubber-tired trailer, the truck could travel at its normal speed, whereas with the steel-tired wagon trailer, speeds of more than four or five miles per hour would have soon wrecked the running gear, wracked the body and so mixed up the contents of the wagon that tools would have been damaged and rendered useless.

Another item of automobile expense that is generally over-looked is that of unnecessary mileage. The speed of a car makes the long way to a job seem of small importance, allows a return for forgotten tools to be made so easily and makes careless routing a matter that is almost impossible to detect. Probably 15 to 25 per cent auto mileage might be eliminated by consideration of these items.

To summarize the elements which should be considered when endeavoring to improve a load curve, we have:

1. With a "one purpose" machine, it should be so designed to give maximum hours of useful work with minimum time out for repairs.

2. "Multi-purpose" machines should be designed to be adaptable to the maximum number of uses spread as nearly over the entire year as possible.

3. Correlated work should be so organized that the equipment is able to work all possible hours.

4. Supervision should be such that duplication of trips of trucks and possible "empty" or unnecessary mileage are avoided and no other work or men are kept waiting.

MICROSCOPIC ORGANISMS IN RESERVOIRS IN RELATION TO THE ESTHETIC QUALITIES OF POTABLE WATERS[1]

By Charles Atwood Kofoid[2]

It is the primary aim of the engineer in charge of the water supply of the community so to devise, maintain and control the physical plant in his charge that the water delivered to the community shall in no wise endanger its health. It is quite a secondary, but nevertheless, humanly speaking, a very important aspect of his responsibilities, that the water supply should in no way offend the sensibilities of the consumer. Water may be dirty and malodorous and contain no germs of disease. It may be crystal clear, refreshing in taste and attractive to the eye, and yet contain the deadliest of typhoid germs. The consumer of such seemingly attractive water would not be prompt in his complaints, but the consumer of the esthetically unattractive and displeasing water supply will harass the engineer responsible for such conditions, and justly so, for it is one of the functions of the water works engineer to maintain the water supply in a condition of attractiveness from the esthetic points of view.

The sensibilities of the consumer will be stimulated and irritated by water which is discolored, dirty, or appreciably malodorous. A certain amount of dissolved matter in the reservoir due to the combinations of mineral salts and organic materials, principally essential oils, serves to add taste and flavor to water which might otherwise seem flat and unpalatable, as is the case in distilled water. Therefore, in limited amounts, organisms and organic substances in water need not deteriorate its esthetic qualities. I shall turn my attention this afternoon to only one of the sources of these disturbances in the esthetic properties of the water supply, namely those odors which owe their origin to the growth of microscopic organisms in reservoir waters.

These growths are in the first place of normal occurrence in every water supply to which sunlight gains access. They are found in all

[1] Presented before the California Section meeting, October 26, 1922.

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countries and all climates and at all seasons of the year, in open reservoirs, lakes and streams, and wherever the radiant energy of the sun gains access to normal water of any origin, from springs, mountain snows, seepage basins, or rainfall. All natural waters contain sufficient quantities of the necessary mineral substances, which together with the carbon dioxide of the air dissolved in the water, provide the constituents necessary for the growth of living organisms. The dust of the atmosphere, the soil, and the runoff of hill and valley, supply the necessary germs and cysts which quickly seed all natural waters. These germs emerge in a few minutes after being wet, and under favorable conditions of temperature and light proceed at once with their multiplication. They are limited in their rate of development by temperature, each according to its kind, occurring at its optimum season and temperature of the year, and giving way to others as the seasons wax and wane, and the optimum conditions at higher or lower temperatures for other organisms follow in their seasonal sequence.

This problem is, therefore, an ever-present one for every water works engineer, no matter what the source of his water supply, no matter how pure it is at the inlet to his reservoir, no matter how clean and sparkling it may be at its source. Sooner or later in every reservoir exposed to the sun, the growths normal to reservoir waters appear in the water supply and run their customary seasonal course.

The sum total of this microscopic life is known to the biologist as plankton, that is, the floating life of water. It is made up of microscopic plants and animals which are invisible to the naked eye, but nevertheless give to the water a color and a turbidity indicative of the kind and the amount of plankton present. These growths are thus one of the principal causes of the turbidities of reservoir waters in midsummer and of the changing colors through the season which experienced observers of reservoirs are wont to notice.

The land and water share alike the capacity of production of an annual crop of vegetation and of animal life feeding thereon, dependent upon the seasonal course of solar illumination. Thus the soil produces its annual crop of grass, the trees their annual crop of leaves and wood, and these in turn support an insect fauna, and under man's control the fields have an annual pasturage value which can be stated in pounds per acre of beef, pork, or mutton. We may also state the result in chemical terms of the amounts of cellulose, starch, sugar, and protein which the vegetable world produces and

assess its food values in terms of calories. In the same way the permanent bodies of fresh water, including reservoirs, which man constructs also produce their annual tonnage of vegetable growths and, if stocked, their annual returns in fish, while the sea produces its seasonal crop of oysters, lobsters, shrimps, fish, and whales which directly or indirectly gain their support from the plant life of the ocean.

This plant life of water, however, differs from that of the land in not building up large growths, such as the grasses, cereals, alfalfa and trees, but in being composed almost wholly of low and simple, primitive forms of vegetable life known as diatoms, desmids, dinoflagellates and algae. These are photosynthetic organisms which multiply with astounding rapidity and produce throughout the year successive crops of microscopic vegetation. These are the primitive food supply of the animal world of the water, which in turn is in part itself microscopic and fluctuates in quick response to the ever-changing quantities of plant life. These quantities of the plant life are produced in rapidly succeeding waves or pulses of production throughout the year and owe their changing dimensions to the fluctuations in light as influenced by the length of the day, the amount of sunlight and primarily the total amount of radiant solar energy which reaches the water. The time factor, the chemical substances in solution, and the temperature modify the amount and the rate at which growth proceeds and thus determine the tonnage per acre of the reservoir.

Quantitative measurements and chemical analysis of production per acre of water surface during the year indicate that the production in the water does not differ greatly from that of the adjacent land in the total amount of organic matter or available food supply which is produced. It is, however, spread over more of the year, is not accumulated in a single harvest time, but recurs over and over again throughout much of the whole year in minor harvests which represent a fraction of the year's production. Chemical analysis of the plankton of the sea or of fresh water differs but little from that of the rye crop, or of alfalfa. The tonnage of fish produced per acre of a reservoir in the course of a year would approximate that of the normal tonnage of beef produced by the meadows on an acre of land.

The accompanying tables of analyses is reproduced from Brandt's investigation of the food values of autumn plankton of fresh water and good meadow hay, and of lupines on the one hand and of Cera-

tium plankton and poor meadow hay and of green rye on the other. These reveal a rather close equivalence of values between fodders of the land and the products of the microscopic water meadows as measured in albumens, fats, carbohydrates, N-free extract and raw fiber.

	ALBUMEN	FAT	CARBOHY-DRATES	ASH
	per cent	*per cent*	*per cent*	*per cent*
Rich meadow grass	20.6	4.5	64.6	10.1
Autumn plankton	20.2–21.8	2.1–3.2	60–68.9	8.5–15.7
Lupine	20.6	2.6	72.0	4.6

	ALBUMEN	FAT	N-FREE EXTRACT	RAW FIBER	ASH
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Poor meadow hay	8.7	1.7	44.5	39.1	5.8
Rye straw	3.5	1.5	38.8	51.3	4.7
Peridinidae, Ceratium	13.0	1.3	39.0	41.5	5.2
Good hay	13.6	3.2	48.2	26.8	8.2
Green rye	12.0	3.3	51.6	27.0	5.8

It is, then, with these normal natural growths in the water of the reservoir that the engineer is concerned who wishes to maintain his reservoir in a condition satisfactory from the esthetic standpoint of the consumer. If it were possible for him to deliver the water from the reservoir directly to the consumer for immediate consumption, there would be little or no danger of complaint unless, perchance, some inquisitive customer would examine his glass of water critically and, holding it up to the light, find it full of floating specks, and examining these with a hand lens would find them to be actively kicking little bugs or squirming worms, the animal life which pastures upon the still more microscopic plant life of the normal reservoir. Unconscious of the biological contents of his glass of water he might derive nourishment from the contents of the water proportionate to the volume of the life therein, for its food values would differ little in kind from those of a fresh salad or oysters on the half shell.

Nevertheless the engineer must count upon the well-known prejudice of the average customer against finding bugs in his drinking water. He is repulsed by them regardless of their food values, and it is the obligation of the engineer to obviate this repulsion.

Another danger likewise confronts the engineer. This arises from the fact that in any distributing plant it is impracticable to deliver the water to the consumer with the plankton in the normal living condition. This arises from the fact that when the water is removed from the light photosynthesis and growth cease in the plant and death and decay quickly ensue, so that what is delivered to the consumer is not a fresh salad, but rather the reservoir's meadow in some stage of putrefaction. The water has in consequence of this more or less of an odor, and this odor is dependent in part upon the presence in the microscopic plants of essential oils not unlike those found in the leaves or vegetation of the land, hence we have odors which may be described as fishy, mouldy, resembling that of the cucumber, or of the geranium, depending upon the organisms predominantly present in the reservoir water at the time. The greater the amount of life present the greater probability of odor, other things being equal. But other things are not equal, for the microscopic flora of the reservoir is as different in kind as is that of the land, and some kinds of plants of the plankton contribute more odor than others. Thus, for example, certain of the blue-green algae quickly bring about in the distributing system and at the hydrant the foul odors of the pig sty when they decay, while larger amount of diatoms may produce the faint odors of the cucumber.

The seasonal sequences of the changes of the vegetation and the accompanying animal life in the reservoir are not unlike those of the land in certain striking particulars. In the first place periods of rapid growth occur at the same seasons of the year in both regions. When the elms and maples are leafing out in early spring in April on the shore of the reservoir, the water itself is flushed with the fresh growth of diatoms and algae. These growths occur year after year with the same regularity as does the bursting of the buds of the maple or the catkins of the willow, and are exquisitely timed to certain sum totals of heat which may be measured by adding up the total heat of each day as the season progresses. In some years the total heat attains the flushing level earlier than others and we have an early spring both on land and in the reservoirs.

The autumn season on land often brings a recurrence of a second and minor period of renewed growth of vegetation, and reservoirs repeat this with an autumnal flush of growth of diatoms, similar to that of the spring, but of lesser volume. The winter is a season of lessened production, but of different species as a whole from that

of the summer, and the summer months a season of recurrent minor flushes not unlike the successive crops of alfalfa that may be reaped from the meadow lands. These, however, do not equal in volume the production of the spring and fall as a general rule.

This fact that the product of a reservoir is subject to fluctuations in quantities with the changes in season, increases the peril which the engineer runs of subjecting the consumers periodically to water surcharged with the odors of decay. These pulses of production come on suddenly without much warning, and disappear shortly after complaints begin to pour into the office. To be forewarned of their coming is to be forearmed.

The means by which the engineer may hold these sources of complaint down below the level of emergence and maintain the reputation of the water supply for its esthetic qualities, are simple and readily attainable by a continuous routine of biological examination of the contents of the water and suitable treatments with copper sulfate as the onsets of objectionable organisms are detected. These treatments will check these growths of the microscopic plant life and thus keep down both it and the animal life dependent upon it, below those levels at which odors are created by the decay of these organisms in the distributing system, especially in those dead ends where the pipe lines are not sufficiently flushed to remove the gases arising from the decay.

The procedure which has been followed for twelve years in connection with the care of the water supply of the city of San Francisco has been as follows: A bi-weekly sample of the life in the reservoir is taken by means of a silk net drawn from near the bottom to the surface. The catch is preserved in 10 per cent formaldehyde and a microscopic examination is made of the kinds of organisms present and the quantitative measurement of their volume is computed to the cubic meter of water. It is possible thus to trace the seasonal occurrence of organisms in the reservoir, to plot these and the total volume of plankton year by year and thus in time to predict the season at which the greatest growths of all important species are wont to recur. This system of frequent examinations makes it possible to detect these waves of production as they are coming on and to prevent their culmination in overwhelming quantities by suitable treatment with copper sulfate.

In this way it has been possible as a result of our experience to reduce the actual volume of vegetable growths in the reservoir to

about one seventh of that prevalent prior to the system of inspection and treatment. It has also been possible to forestall and prevent the occurrence of waves of heavy production and thus to practically eliminate complaints arising from unpleasant odors in the water supply. These odors become specially evident when the water is warmed and develop to a maximum evidence in hotels and in homes in which a constant supply of hot water is maintained in tanks. When this is withdrawn at the washbowl or the bath tub the odors at once become apparent.

These odors are also accompanied in some instances by two other sources of offense. The first of these is a discoloration of the water, which in the case of certain organisms such as Ceratium, is very noticeable. This organism gives a rusty color to the water as well as a vile odor. A second source of disturbance arises from the fact that the growth of the microscopic vegetation favors the growth of the animals which feed upon it and thus increases the number of water fleas, small crustacea, insect larvae and worms which are found in all normal reservoirs. These sometimes reach the consumer and find their way to the table where they excite unfavorable comment on the efficiency of the engineering control of the water supply. In other cases they merely add to the volume of odor which accumulates in the dead ends of a distributing system, for when the plant life decays they very often are also killed, and, decaying more slowly than the smaller plant, may reach the consumer in a partially decayed state.

Every carefully controlled and well regulated water supply of a large community should conduct a systematic series of observations on the plankton of its reservoirs and thus maintain the water in proper esthetic condition for the satisfaction of the consumers. The problem is a more difficult one in the case of small installations where the engineering staff is small and the expense of biological examination disproportionate to the results attained. In these instances, it would be well for the engineer in charge to familiarize himself with the biological control of odors and to conduct these examinations at the times which experience in the course of several years can teach him to be the times of greatest danger from contamination.

The organisms most to be feared in California as sources of odors are in our experience somewhat numerous and of unequal importance. Two outstanding ones have been the source of much of the trouble in the reservoirs of San Francisco. One of these is *Ceratium hirun-*

dinella, a dinoflagellate which is capable of extraordinarily rapid multiplication, the discoloration of the reservoir water to a rusty brown, and of creating an almost unbearable stench at the hydrant. The amounts produced are very large and the times of the year at which production may assume dangerous proportions extend throughout most of the twelve months. This organism is related to those which produce the phosphorescence of the sea and the outbreaks of red water along the coast of Southern California when great numbers of fish are killed and the fisheries are temporarily suspended. They or related species are also undoubtedly the occasion for the Bible account of the turning of the Nile to blood and the stench which followed.

The second principal odor-producing factors in plant life here and elsewhere are the blue-green algae. These occur especially in late summer from about the first of August to the end of September. The species which create trouble here are not the same as those reported in the eastern United States. *Anabaena* has been most notorious in Massachusetts and New York in creating a pig pen odor. It is present here but has never been as abundant as another alga known as *Cylindrospermum*, which is our principal source of trouble from the blue-green group. This has a tendency to rise to the surface, to drift with the wind, to accumulate in great quantities locally so that the water has the appearance and consistency of bluish soup. This tendency is one of the sources of danger when the outlet is in the area of this accumulation.

Certain features of reservoir construction have a bearing upon the control of odors in water supplies. They are easily derived from certain biological principles which control growth of organisms. In the first place the richer the water is in nitrates and phosphates the greater the probabilities of rapid growth, hence soil stripping or coating the bottom of the reservoir with clay to seal off organic deposits such as peat or swamp material, are desirable to prevent alga growths. In the second place, the greater the surface area of the reservoir the greater the relative production with respect to the volume of water stored, hence the elimination of shallow places by filling or dredging is desirable if economically feasible. In the third place, water which has once been filtered, or spring or seepage water, should wherever feasible be stored in the dark so as to impede the growth of plant life. In the fourth place, it is often possible by control of the level and location of the intake or by knowledge of the

relative development of the plant life in different reservoirs in one system to draw water from levels not so heavily contaminated by plant life, or from reservoirs less productive and thus to dilute the supply sent through the pipes to the consumers to a level of production which does not bring the odors into evidence.

Every reservoir system is more or less of a law unto itself, and the organisms thriving therein are not necessarily those of the adjacent reservoir even in the same system. Subtle differences of seepage or chemical differences inhibit one growth or another, and one must learn by experience rather than rely upon inferences from knowledge of other reservoirs or published accounts.

In the main, however, the organisms of fresh water throughout the world are much the same, the seasonal course of production has much in common in different localities and in different years and much is to be gained from this common background. It should be supplemented by accurate knowledge of local conditions accumulated year by year and recorded in an orderly and systematic manner. Graphs of the annual production of plankton in cubic centimeters per cubic meter of water for each reservoir of a city's system, or of those reservoirs from which the distribution is made to the consumer, will in time become valuable aids in guiding the engineer in the prevention of objectionable odors and in the reduction in the costs of treatment.

FUEL OIL ENGINES VS. STEAM ENGINES FOR SMALL WATER PLANTS[1]

By George T. Prince[2]

The primary object in presenting this paper is to arouse a discussion which ought to be helpful in determining the respective merits of fuel oil engines and steam engines when applied to small plants. Through some misunderstanding, the title as intended by the speaker of Fuel Oil Engines vs. Steam Engines for small plants appears in the program as Fuel Oil Engines vs. Steam Engines in Small Water Plants. To confine our remarks to water plants alone, to the exclusion of a combined electric and water plant, would result in greatly curtailing the opportunities for discussion. It might be contended that, if steam is not as economical as oil as a heat agent in a combined electric and water plant, it certainly would become less economical when used only for pumping water.

It is assumed that a considerable number of members present have to do with combined electric and water plants and are interested in whether, in operating small combined electric and water plants, fuel oil or steam engines should be chosen. By small plants, we mean plants that supply electric current and pump water for communities of less than 10,000 population.

The speaker has been more and more impressed with the fact that many villages and small cities using steam power plants are not able to meet maintenance and operating expenses. In numbers of instances coming under our notice the town is not able to pay the coal bill, to say nothing of fixed charges and labor. Relief from this deplorable condition is in many instances being obtained through purchase of current for municipal purposes from transmission lines.

To the speaker it would seem decidedly advisable, under present conditions, that towns of less than 10,000 population should not install steam driven power plants.

As a first step, let us consider simply the thermodynamics of the question. These small power plants will use from seven to eight

[1] Presented before the Iowa Section meeting, November 1, 1922.

[2] Consulting Engineer, Omaha, Nebraska.

pounds of coal per K.W.H. If we assume a thermal value of coal as 10,000 thermal units, seven pounds will represent 70,000 heat units. One K.W.H is equal to 3411 heat units. It is therefore apparent that we would obtain a thermal efficiency represented by the expression $\frac{3411}{70000} = 0.049$. Compare this result with that obtained from oil drive. We will assume 8/10 pound of oil per K.W.H and 20,000 heat units per pound of oil, we then have $\frac{3411}{16000} = 0.213$ thermal efficiency, or over four times the steam efficiency. The latent heat of steam is largely responsible for this great loss. In large plants, some of this latent energy is recovered, but in small plants, such as we have under consideration, little of this 80 per cent loss, represented by this latent heat, is recovered.

Like the fellow that votes the Democratic ticket because his grandfather voted for Andrew Jackson, so we continue to use water, which is one of the poorest heat agents, because Watt happened to utilize it. Our reason for this is doubtless due to the fact that it is so generally distributed over the earth's surface and hence generally available, though undoubtedly it will later be discarded for a more scientific and efficient medium.

Americans are proverbially more wasteful than other peoples. About thirty years ago the speaker was in the employ of an Eastern firm in designing and installing gas producers in many large industrial plants such as Bethlehem, Pencoyd, Cambria, Homestead, etc.

When traveling in connection with this business, we often passed through the coke producing district of Pennsylvania and noticed the deplorable waste of monoxide gases that were emitted from their coke ovens. Years after, measures were adopted to utilize these gases and this criminal waste was largely eliminated along lines that had been in use in Germany for many years.

The speaker used to try to have persons in the Pittsburg district shut off the natural gas wells that were allowed to waste the gas when not in use. Many Pennsylvania towns never turned off the gas lights from one year end to the other. In no other nation in the world would such prodigal waste be allowed.

In the same way steam engines have been installed in municipal power plants, which years ago were justified when coal was less than one-third of its present cost. Today, in the opinion of the speaker it would be far better to discard the small steam plants which have

been rendered obsolete by the high prices of coal and secure economy made possible by the development of fuel oil engines, which, as shown above, are four times more efficient than the steam engine, using seven pounds of coal per K.W.H.

We have recently received a report from the engineer of a water works plant in a western city of 25,000 population. This plant was operated by steam prior to 1915, but in that year was changed over to a full Diesel plant. This letter states that, when steam-operated, the plant consumed from 3400 to 4000 pounds of coal per million gallons of water pumped, and current was purchased at 3½ cents per K.W.H.

The engineer gives the operating expense as follows:

3804 pounds of coal at present prices in bin ($9.35 per ton)	$17.78
Estimated cost of lubricating oil	.50
Cost of 260 K.W.H. at 3.5 cents	9.10
Total cost per 1,000,000 gallons	$27.38
Present cost, using fuel oil	$ 6.93

Saving, $20.45, equal to over 73 per cent

We quote the following from the engineer's report:

> These oil engines have been in continuous use, except during periods of overhauling, since they were installed, and we consider them practically as good as new.

Since 1915 the above city has installed two 520 H.P. oil engines for electrical purposes.

Attention is called to an editorial in the September 12, 1922 issue of "Power" in relation to oil engines and small power plants.

A city in Texas having a population of approximately 3500 has in service a Diesel engine installed in 1915. During 1921 this engine operated 8629 hours (98.47 per cent) at an average cost of:

For fuel per K.W.H.	$0.0059
Supplies, maintenance and lubrication	0.0039
Labor	0.0048
Total average cost per K.W.H. for 680,193 K.W.H. generated, average output, 10.08 K.W.H. per gallon of fuel oil	0.0146

The above figures of cost do not include interest and depreciation.

An Iowa town of 1248 population has two Diesel engines which were installed in 1917 and 1920.

Operating costs per K.W.H for 1921 were as follows:

Fuel oil	$0.0060
Lubricating oil	.0007
Attendance	.0084
Repairs	.0004
Total average cost per K.W.H. for 563,685 K.W.H. generated	$0.0155

The above figures do not include interest and depreciation.

A Kansas City town of about 3500 population has three Diesel engines in service which were installed in 1915, 1917 and 1920. All expenses including interest, taxes and depreciation per K.W.H for 1921 amounted to $0.0272, the fuel oil cost alone being $0.0044.

A particularly interesting case is that of a Kansas town which formerly operated a steam plant. About eleven years ago steam was replaced by oil drive, coal at that time costing $1.95 in the bin. Later the city secured contracts with coal mines adjacent to the city limits for furnishing electric power for operating coal mining machinery, and additional oil engines were installed. At that time the cost of coal in the bin was $3.05 and the cost of oil was $0.04¼ per gallon in tank lots.

We submit that it is a significant fact that oil drive is used with which to mine coal. If coal operators find it cheaper to buy electric current generated by oil engines, it is difficult to understand how towns located at a distance can logically use steam power, having regard to the fact that the average small steam engine develops but five per cent thermal efficiency and fuel oil engines from 21 to 33 per cent, dependent upon the load and type of engine employed.

On pages 96 and 97 of the July 19, 1922, issue of "Power" is shown a load curve of a semi-Diesel oil engine plant located at Bonner Springs, Kansas. The superintendent of a Diesel plant in Louisiana plotted this curve and at the time made a 24-hour run of his plant. The resulting curves were very nearly alike. The semi-Diesel plant developed a duty of 8.42 KWH per gallon of oil and the Diesel plant, 8.89 KWH. The performance reduced to cost per KWH, assuming oil at 6 cents per gallon, indicates for the semi-Diesel, $0.00713 and for the Diesel, $0.00675, whereas coal at $8.00 per ton and 7 pounds per KWH, would cost $0.028.

The speaker recently reported on a waterworks property which is used to supply water to a city of 4000 population. The water is first pumped from wells to a filter plant under a head of about 65 feet

and then repumped into the city under a head of 200 feet. The average cost of coal during 1921 was $6.67 per ton and the cost for the year was $2811.00. The yearly pumpage was 113,400,000 gallons, which indicates a fuel cost of 2½¢ per 1000 gallons. In this instance water could have been pumped at a fuel cost of 1.2 cents per 1000 gallons.

In a Western town in which the firm with which the speaker is connected installed a semi-Diesel pumping plant, water was pumped against a head of 250 feet at a fuel cost of 1 cent per 1000 gallons, equal to 8/10 cent per KWH.

Many more instances could be cited where oil drive has replaced steam. Cases have come to the speaker's attention in which financial failure of power plants has been turned into paying investments by substituting oil for steam engines.

We will add one more case which has come to our attention and this in a quotation taken from a letter received from a city manager of an Iowa town.

The municipal water plant was installed in 1883 and has been steam operated from that date until September 1, 1921, using as the principal prime mover for the past twenty years a Laidlaw-Dunn Gordon, Cross Compound, Condensing Pumping Engine of 1.5 million gallons capacity per 24 hours, and as an auxiliary a Worthington Tandem Compound, Non-Condensing Pump of the same capacity. These units are in good condition and the duty performance is I believe all that could be expected of this type of equipment.

On September 1, 1921, we installed a three stage, centrifugal pump of 800 R.P.M., direct connected to a 75 H.P., 2300 volt, G. E. Induction Motor, the steam equipment now being used as an auxiliary. We have not had occasion to use the steam equipment since the installation of the motor driven unit, which will indicate the reliability of the present equipment.

The municipal electric plant which was put in operation April 1, 1920, furnishes the current needed to pump the city water supply, is housed in the same building and the same attendants operate both plants. This arrangement has resulted in such a marked saving in pumping costs that, viewed from a comparative basis of former operating conditions, it might be said that the pumping now costs us nothing. The idea I mean to convey is: that, *with no greater fuel expenditure* than was formerly necessary to pump the water supply by steam power, by the use of the Diesel Engine and the installation of electrical equipment we are now pumping the water, furnishing current for the Boulevard Lighting System and selling service to the amount of nearly $1500.00 per month.

This installation consists of one 250 B.H.P. Diesel Engine direct connected to a 225 K.V.A. Generator and has furnished continuous 24 hour service since May 1, 1920, the only shut downs being for periods of about two hours each Sunday afternoon, for the purpose of valve changing and general inspection.

No expenditures have been made for repairs and no parts have been renewed by reason of breakage or wear.

No adjustments of main bearings have been made. The alignment is practically undisturbed, but one adjustment of connecting rod bearings has been made. No trouble has been experienced from faulty lubrication, air injection or water cooling. Cooling jackets are practically free from scale. Fuel consumption has not exceeded the makers' guaranty. Fuel used is 32/36 gravity gas oil, average cost, during period of operation, 6 cents per gallon in the storage tanks at the station.

No trouble has been experienced in obtaining an adequate supply of fuel oil. Fluctuation in price has not been sufficient to cause an unbalanced revenue return.

In addition to the above, it might be well to refer to the pumping station at Casper, Wyoming, which is a city of about 20,000 population. One semi-Diesel engine of 200 H.P. capacity supplied that city with water, without stand-by service, for a period of over four years and during that time operated 135 days continuously, 24 hours per day without shutdown. At the end of that time the engine was stopped for a period of a few hours in order to grind a valve and was again put in service and run for one hundred days at twenty-four hours per day.

At the end of four years this machine was supplemented by a second machine of the same type and capacity. The cost of renewing the first machine so that it was practically as good as new amounted to $150.00

From the speaker's observation, it would appear that the fuel oil engine of today is a dependable machine and economical in service.

We are adding some tabulated data of economical results which may be obtained by the use of oil and steam engines. We have assumed towns of 1000, 2500, 5000, and 10,000 population to be supplied with power for furnishing electric lighting and power and for pumping required water supply.

For 1,000 population we assume output of 550 K.W.H. per 24 hours
For 2,500 population we assume output of 1800 K.W.H. per 24 hours
For 5,000 population we assume output of 3600 K.W.H. per 24 hours
For 10,000 population we assume output of 7500 K.W.H. per 24 hours

These assumptions may be at considerable variance with special cases, but they are based upon observation and information from various sources. It is believed that unit costs will fairly represent average results.

In closing, the speaker desires to state that he is not interested in oil engines, other than from the stand-point of an engineer desiring to obtain the most economical results in the interest of his clients.

Having been in charge of steam plants for over thirty years and in charge of two of the largest privately owned water plants in the country, viz: Omaha and Denver, I fully appreciate all advantages attached to steam power plants. We must recognize however the benefits accruing through improvements in the art of generating power and we affirm that it is our belief that oil engines in their present state of development are far more economical in furnishing electrical power and pumping water for plants that serve communities of 10,000 people or less than are steam engines.

Tabulation showing approximate cost of power plants for towns of various sizes and operating expenses for steam and oil power plants

POPULATION	PROBABLE ANNUAL OUTPUT IN K.W.H.	COST OF POWER PLANT		ANNUAL MAINTENANCE AND OPERATING EXPENSES		UNIT COST PER K.W.H.	
		Steam	Oil	Steam	Oil	Steam	Oil
		dollars	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*
1,000	198,000	35,300	31,500	13,874	8,992	0.070	0.045
2,500	648,000	54,650	53,200	19,798	15,063	0.030	0.023
5,000	1,300,000	82,000	91,300	30,405	26,492	0.023	0.0204
10,000	2,700,000	117,500	103,000	49,348	39,303	0.0183	0.0146

The above Maintenance and Operating expenses include labor, fuel and lubricating oil, repairs, 6 per cent interest on investment, depreciation based on 4 per cent sinking fund, life of oil engines assumed as 15 years, all other property 25 years.

Price of coal $8.00 per ton for 1000 and 2500 population—Hand firing—Evaporation 6–1.

Price of coal $7.50 for 5000 population—Mech. Stokers—Evaporation 8–1.

Price of coal $7.00 for 10,000 population—Mech. Stokers—Evaporation 8–1.

Price of fuel oil 6 cents per gallon.

Price of lubricating oil 60 cents per gallon.

SOME NOTES ON THE HYDRAULICS OF WELLS[1]

By Melvin L. Enger[2]

In discussing the laws of flow into wells it is convenient to divide them into three classes: (1) wells in fissured rock, (2) ordinary wells, (3) artesian wells. Wells in fissured rock present such eccentricities that it is impossible to derive mathematical expressions of general application. Ordinary wells are those in a porous formation (usually sand or gravel) in which the surface of the water table is exposed to atmospheric pressure through the porous material above. Artesian wells are those in a water bearing stratum overlain by an impervious layer, and the water level in the well is at all times higher than the top of the water bearing stratum. Artesian wells may, or may not, be flowing wells under this definition.

In Turneaure and Russell's "Public Water Supplies," the following formulas are derived for the yield of ordinary and of artesian wells:

For ordinary wells

$$Q = \frac{\pi\, kp\, (H^2 - h^2)}{\log_e \frac{R}{r}} \tag{1}$$

For artesian wells

$$Q = \frac{2\,\pi\, kpt\, (H - h)}{\log_e \frac{R}{r}} \tag{2}$$

In which Q = yield of well.

p = porosity of water bearing formation.

k = a constant depending upon the effective size of the grains in the water bearing formation, upon the porosity, and upon the temperature of the water.

H = static water level in the well above the bottom of the water bearing formation.

[1] Presented before the Illinois Section meeting, March 29, 1922.

[2] Professor of Mechanics and Hydraulics, University of Illinois, Urbana, Ill.

h = water level in the well above bottom of water bearing formation, while well is being pumped.
R = radius of influence.
r = radius of well.
t = thickness of water bearing formation in artesian wells.

Equation (2) may be written

$$Q = K(H - h) \tag{3}$$

in which K is the "specific capacity" of the well, that is, the yield per foot of drawdown. Equation (3) may also be applied to ordinary wells when the drawdown is not too great. The specific capacity becomes somewhat smaller as the drawdown increases, but in the case of artesian wells the change in specific capacity is usually not great.

Whether a well is of the ordinary or of the artesian type can be easily determined by noting the lowering of the water level when pumping begins. If the water level falls quickly until the equilibrium level is reached the well is of the artesian type.

The equation for the lowering of the water level in an artesian well after pumping begins is easily derived. Let z = the drawdown in feet any time t seconds after pumping begins. Let Q = rate of pumping, and A = area of cross-section of the well. Then

$$Qdt = Adz + Kzdt$$

Integrating

$$t = \frac{A}{K} \log_e \left(\frac{Q}{Q - Kz}\right) \tag{4}$$

Similarly the equation for the recovery of water level in the well when pumping is stopped is

$$t = \frac{A}{K} \log_e \left(\frac{z_o}{z}\right) \tag{5}$$

in which z_o is the drawdown in the well at the instant the pump stopped and z is the drawdown t seconds later.

As an illustration of the use of equation (4) assume a 12-in. artesian well, specific capacity 0.1 cu. ft. per second per foot of drawdown, and assume that pumping begins suddenly at the rate of 1 cu. ft. per second. The final drawdown for the given specific capacity

will be 10 ft. The water levels at different intervals calculated from equation (4) are tabulated below.

DRAWDOWN	TIME AFTER PUMPING BEGINS
feet	*seconds*
0	0
1	0.8
2	1.8
3	2.8
4	4.0
5	5.5
6	7.2
7	9.5
8	12.7
9	18.1
9.9	36.2
9.99	54.3
9.999	72.4

While it is not possible to derive a simple equation for the rate of lowering of the water level in an ordinary well, it is evident that the lowering will be relatively very slow on account of the great amount of water which must be taken out of underground storage. Rough calculations show that many days would be required to lower the water level in an ordinary well of the diameter and specific capacity given above as much as the artesian well is lowered in one minute.

Equations (1) and (2) refer only to wells having remote sources of supply. Equations for the flow into wells by percolation from the area adjacent to the well are given by Robert E. Horton in the Journal of the American Water Works Association of March 1921, page 167. Mr. Horton's solution is based on the assumption that there is a minimum constant slope necessary to cause water to move and that for slopes flatter than this there is no appreciable flow. This minimum gradient is stated to be 1 in 260 for moderately coarse sand and 1 in 175 for fairly find sand. The writer is unable to agree with the premise that such relatively steep slopes are required to cause flow. By making these assumptions Mr. Horton derives simple equations and gives illustrations of their use.

The equations for the flow of water into wells supplied by percolation from the adjacent area, may be derived as follows:

Ordinary wells. The same notation is used as for equations (1) and (2), and in addition let q = average rate of infiltration in cubic feet per second per square foot of infiltration area, Q_x is the rate of flow in cubic feet per second through the cross-sectional area a_x at distance x from the well, where the depth of ground water is y Then

$$Q = \pi R^2 q \qquad a_x = 2\pi xy$$

$$Q_x = \pi (R^2 - x^2) q = k a_x sp = k 2\pi xy \frac{dy}{dx} p$$

$$\pi q \int_x^R (R^2 - x^2) \frac{dx}{x} = 2\pi kp \int_h^H y dy$$

Integrating

$$H^2 - h^2 = \frac{Q}{\pi kp} \left(2 \log_e \frac{R}{r} - 1\right) \tag{6}$$

$$H^2 - y^2 = \frac{Q}{\pi kp} \left(2 \log_e \frac{R}{x} - 1 + \frac{x^2}{R^2}\right) \tag{7}$$

Equation (7) is the equation of the curve of the ground water surface, and (6) is the equation for the yield of the well when pumping has continued until equilibrium has been obtained. The value of R changes with the season and rainfall, but it may be taken to represent the average for the year.

Semi-artesian wells. There can be no infiltration in the vicinity of an artesian well with an *impervious* overlying layer. But wells in the glacial drift seem, in some cases at least, to be supplied by means of percolation from the area adjacent to the well. Yet such wells exhibit the artesian characteristics of quick drawdown and quick recovery. The behavior of these wells can be explained by assuming that the clay roof overlying the water bearing formation is sufficiently pervious to allow a few inches of water a year to percolate through it. Such wells might be called semi-artesian wells. The derivation of the equation for curve of the water surface and of the yield is similar to the one given above. The results are:

$$H - y = \frac{Q}{4\pi kpt} \left(2 \log_e \frac{R}{x} - 1 + \frac{x^2}{R^2}\right) \tag{8}$$

$$H - h = \frac{Q}{4\pi kpt} \left(2 \log_e \frac{R}{r} - 1\right) \tag{9}$$

For conditions in the vicinity of Urbana, Illinois, the equations reduce to

$$H - y = \frac{Q}{40{,}000}\left(2 \log_{10} \frac{R}{x} - 1 + \frac{x^2}{R^2}\right) \tag{10}$$

$$H - h = \frac{Q}{40{,}000}\left(2 \log_{10} \frac{R}{r} - 1\right) \tag{11}$$

In the last two equations Q is expressed in cubic feet per day, H, h, R and r are in feet, and it is assumed that the percolation into the water bearing stratum is at the rate of 5 inches per year. Such equations are valuable because they supply a rational basis for spacing wells, as well as indicating the effect of the diameter of the well.

The formulas which have been given neglect to take into account the loss of head in the well screen. Experience in the operation of wells has shown that in many cases the poor yield of a well is due to a clogged screen. The function of the screen is to keep sand out of the well and to let the water in. When a screen is set in sand it is evident that some of the sand grains will obstruct the flow through the holes in the screen. Fine sand will cause more obstruction than coarse sand. Drilling wells of large size and packing gravel around a coarse screen has often been found satisfactory, but in some such wells fine sand has continued to come through the screen during several years of operation, to the great detriment of the pump. The tendency is to use gravel which is too coarse. Graded gravel containing large stones should never be used, because the porosity of graded gravel is low, and there will generally be relatively large channels through the gravel wall which will allow fine sand to drift into the well. The ideal material to place around the screen is sand, or gravel, with grains all of the same size. The size of the grain to be as large as will keep the fine sand of the formation from drifting. The screen may then be quite coarse. It should be emphasized that the use of gravel so coarse that it will become choked with fine sand is worse than no gravel at all.

USE OF DEEP WELL WATER TO SECURE ALKALINITY FOR TREATING SURFACE WATERS[1]

By Geo. P. Womble[2]

Upon putting into service our new filtration plant it was soon found that, owing to the amount of alum required to get proper coagulation, it was necessary to use a very large quantity of soda-ash, which, aside from the excessive cost entailed, proved difficult to regulate properly.

After investigating the problem it was decided to drive a test well on our property to ascertain the advisability of using deep well water for securing the desired alkalinity. Upon completion of the well, tests showed the alkalinity of the water to be around 300 p.p.m. which for all intents and purposes was satisfactory. The test well was driven to a depth of 60 feet, at which level a sufficient quantity of water was obtained.

Upon finding a sufficient quantity of water suitable for our purposes it was decided to sink five 3-inch wells, which furnished an ample supply for our use. These wells were spaced over an area of about 200 feet square, rectangular in shape. The casings were all brought to one header and carried to the pump, which is of the triplex pattern, with a capacity of 300 gallons per minute. This was formerly used in our old water plant for pumping from wells, and has proven highly satisfactory in its new location.

The capacity of the filtration plant is 1,000,000 gallons per day. At present there is a consumption of about 450,000 gallons per day. The alkalinity of the raw water varies from 4 to 5 p.p.m. Previous to the employment of deep well water for correcting the deficient alkalinity, we used alum at the rate of 500 pounds per million gallons, and soda ash at the rate of 300 pounds per million gallons. We now use about 300 pounds of alum per million gallons and no soda-ash.

[1] Presented at North Carolina Section meeting, November 15, 1922.

[2] Superintendent, Municipal Electric and Water Department, Washington, North Carolina.

The ideal arrangement for using well water for correction of deficient alkalinity is to place a meter in the discharge line between the pump and mixing chamber and by metering the raw water supply the alkalinity can be regulated to a nicety, resulting in a quality of water greatly to be desired. The amount of well water used is regulated by a gate valve placed in the suction line to the pump, and is varied in accordance with the results of laboratory tests of the filtered water.

It is not the intention of the writer to go into the subject of costs covering the installation of the deep well machinery, or the savings realized by the use of well water for acidity correction, as each case must be worked out according to local conditions, and will vary according to nature of soil, freight rates, labor costs, etc. It has been our experience, however, that this method of treatment is far more satisfactory than the soda-ash or other treatments. The savings in our case have reached in some instances as much as five dollars per day, varying of course with the price of soda-ash and quantities used.

The original layout as described was enlarged a year ago by adding two more wells of the same size and connected to the original suction header. This enlargement was not made on account of a lack of water for correction of deficient alkalinity, but to increase our supply to the point where we could depend upon the wells as an auxiliary to our regular supply in event of the failure of our filtration plant or other cause. We were fully justified in making this additional enlargement by the conditions which presented themselves in less than sixty days after the completion of the work. Being situated on the Coast our water supply may become brackish upon a continuance of winds from the southeast, which carry the tide into the creek from which we obtain our supply. During the period referred to, the prevailing winds from the southeast lasted for about sixty days and caused the surface supply to become salty, whereupon our well pump was brought into play and furnished our total supply during the whole period. The water from the well supply, aside from the hardness, was satisfactory and much more palatable than that from our regular supply during this period.

FORESTATION, A PROBLEM IN PUBLIC SERVICE ACCOUNTING

By Edward Field[1]

Within a comparatively few years the authorities controlling both municipal and private water supply systems have been engaged in a work known as "forestation and reforestation." The importance of this branch of their operations as a means of protection of the water supply sources and for hygienic reasons is well recognized. Just to what extent "forestation" on watersheds influences the conservation of water is a hydrological question which has been the subject of many discussions by engineers and regarding which there is a diversity of opinion. The bibliography of the subject is extensive, but it is not my purpose in this discussion to introduce the various points involved in the question; but, since they have become recognized factors in the management of water plants, it will be assumed that there is no question as to the result to be attained. This is no more fully set forth than in the admirable paper on "The Relation of Water Resources to Forestry" presented by Thorndike Saville in an address before the North Carolina Forestry Association at Asheville, North Carolina, on June 10, 1920. It embodies all the essential facts necessary to a discussion of the subject.

His paper is divided into three divisions, "Hydrological," "Public Welfare," and "Economic." It is with that portion relating to public welfare that we are most concerned. In connection with its application to private and municipal water plants, under the caption of "Protection of Public Water Supplies," he states, "The protection of impounded public water supplies from all possible sources of pollution demands ordinarily a minimum use of the watershed for domestic or agricultural purposes. The best kind of watershed from a hygienic standpoint is one thickly wooded. Cities are rapidly coming to pursue a definite policy of forestation upon

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their watersheds used for domestic water supplies. This policy is carried out from the double relation of health and economy. Closely related to the forestation of watersheds is the protection of reservoirs from dust and the effect of decreased evaporation due to adjoining woods."

Forestation has brought into the financial operations of such water supply systems an accounting problem which, in its beginning, was not seriously considered as a distinct proposition, but it has become, by reason of its increased magnitude, an item of importance in the accounting systems of such companies. In most of the states in the Union the Public Service Commission (or by what other name it may be called) has jurisdiction over water companies either private or municipal, or both. In most of such states uniform systems of accounts have been promulgated, telling how and in what manner each item of expense and revenue shall be treated, but in none of the uniform systems of accounts at present in operation is there any reference to how this important item shall be treated. It is a new question, and the various companies and municipalities are practically left to determine for themselves how the various items entering into it shall be charged or credited. It would seem that the time has now arrived when a policy should be adopted and a consistent method prescribed for taking care of the cost and revenue incident to forestation. To outline a definite plan for this is attended with some difficulties. Yet some definite scheme must be devised which will meet all the exigencies of the situation and which shall be fixed upon as a proper method of taking care of the accounting side of this question. In some of the states the matter of accounting for public utilities is partially regulated by the statute law of the state, while in others it is solely under the control of the Public Service Commission. There may also be legal questions which may be involved under certain circumstances. Section 6249 of the General Statutes of the State of Connecticut, Revision of 1918, provides as follows:

"Every person claiming the right of possession, whether as mortgagor or otherwise, to any land subject to any mortgage duly executed and recorded, who shall, while such mortgage is unreleased of record, impair the value of the premises subject to such mortgage by removing, destroying, or injuring any buildings or fixtures on the land so mortgaged, or by cutting wood not necessary for fire wood to be used on said land by the family of the mortgagor, or by any other means, without the consent in writing of whoever appears

of record to be the owner of, or interested in, such mortgage, and with the intent to defraud any owner or person interested in such mortgage, or with the intent to lessen the value of the property subject to such mortgage to the injury of any person owning or interested in such mortgage, shall be fined not more than $100 or imprisoned for not more than three months, or both."

The effect of this statute might preclude a water company whose property was subject to a mortgage as security in pursuance of a contract on the issue of its bonds from impairing its value by cutting timber from such mortgaged premises, and might require such company to set aside the value of any wood so cut or removed, or the proceeds from the sale of any wood cut, as a deposit in lieu of mortgaged property sold to be accounted for in due time to the mortgagee, and if such cutting or removal was in conflict with any of the provisions of said law, such company might be penalized for such illegal proceedings.

From an accounting standpoint, we are met with three viewpoints: Is the expense a proper item of operating cost or is it a proper charge to capitalization? On the other side, is the revenue incident to forestation an operating revenue, or is it an income applicable to the investment which the municipality or the private company may have in its plant and equipment, or is it a distinct and separate accounting problem?

The watershed of a water supply system usually consists of large tracts of wild country, heavily wooded, of hills and vales, left to its natural development. The wooded territory is subject to many changes. Forest fires may sweep over and devastate many acres of what was once thickly grown and heavily shaded woodland tracts, wind storms and sleet and ice break down and destroy large trees and the thick underbrush, and the debris thus created interfere with the future growth of other trees. The destruction of large tracts by fire leaves the land open to the full force of heavy rains and melting snows, causing an erosion of the soil which may divert the brooks and streams and to some extent destroy the sources of water supply. For many years, and until within a comparatively few years, no attention was paid to this, but it is now recognized as a hydrological problem which must be met and the damage repaired or prevented if the water supply system is to be maintained up to its standard, its efficiency increased, or its supply protected. Thus there has come about the necessary expenditure of large sums of

money for this purpose. Watershed property, in its first cost to the municipality or company controlling it, is usually a small part of the cost of the whole water works system, even though it may be a very important part of such a system.

The operating expenses of a water supply system are usually divided into three major classes:

Water supply operations
Water supply maintenance
General and miscellaneous expenses

Operating expenses are usually intended to include all items of expense that have been necessarily incurred in being prepared to serve, or in serving, the public as a water company. This includes the expense of maintaining intact the organization of the utility, the collecting, pumping, distribution and sale of water and all processes necessarily incident thereto.

Maintenance expenses are intended to provide for the upkeep of the system and cover all expenditures for current or ordinary repairs, renewals or replacement of property resulting through wear and tear or through those casualties which are incidental in the operation, and which expenditures are necessary in order to keep up the productive capacity of the plant to its original or equivalent state of efficiency.

General and miscellaneous expenses are those expenses particularly connected with the administration of the property, including its accounting and commercial expenses, costs of injuries or damages, general insurance charges, and similar charges of a miscellaneous character.

Water supply operation expenses are usually subdivided into four divisions for the allocation of costs of operations incident to its collecting, its purification, its pumping, and its distribution systems.

Into which one of these several classes would the cost of forestation naturally fall? The expenses particularly applicable to the collecting system include wages and expenses for inspecting and policing, of caretakers and other employees, but does not include any items of repairs. The expenses incident to the purification system include the wages of men employed in the purification works, their personal and incidental expenses, the expenses of running the works, including the cost of chemicals and supplies, labor for cleaning

basins and works, removing ice, scraping and cleaning purification apparatus, and the heating and lighting and other incidental expenses applicable to structures. Pumping system expenses include the salaries or wages and personal expenses of pumping station employees, fuel, water power, electric power, electric lighting, gas for power and lighting, janitor services, oil, waste, supplies, etc. Items of repairs are excluded. Distribution expenses include the cost of inspecting, guarding and caring for the transmission mains and accessories, storage reservoirs, tanks and standpipes, the cost of inspecting, testing and caring for the distribution mains and accessories, service pipes, meters, etc., and all expenses in connection with the transmission and distribution of water, except the cost of repairs. Certainly any cost incident to forestation would not, unless remotely, fall within the line of expenses applicable to strictly operating costs. It is not necessary to enumerate the various items of costs of maintenance. Maintenance costs of these same several divisions include and almost entirely consist of expenses incident to repairs and keeping the various parts of the water system in proper condition. Forestation costs do not seem to come within the various items which make up maintenance expenses, and such costs of forestation may hardly be regarded as general or miscellaneous expenses. If the costs of forestation are not properly to be included in costs of operation or of maintenance, then they must be excluded from consideration as being applicable to the cost of operating the plant.

In the accounting systems of public utilities provision is made for taking care of all expenses and income applicable to other classes of operations which are designated as outside or auxiliary operations. Outside or auxiliary operations of a public service company may be defined as such operations as are not incidental to the particular business of the utility. Forestation then would not come within this definition, for reforestation is incidental to the business of a water company.

It may be contended that forestation, being in the nature of bringing about a condition that has resulted from various causes, might be considered in the nature of repairs. Maintenance repairs of a water works system are generally considered to be the expenses necessary to keep the several parts of the constructed system in a proper condition for a continuation of the service for which it was originally constructed and to produce immediate results.

Forestation is a process of bringing about a new condition. The results of forestation are only shown in years ahead. It is a precarious process. In some instances the planting of trees has resulted in the trees dying and two or three attempts being made before a species of trees could be found that would thrive in the soil. The unusual expense incident to the process would seem to preclude it from being charged as an expense of operating the plant. The only other division of accounts open for costs of forestation is the investment account. The investment account of water supply companies is, generally speaking, what is called the "Plant and Equipment," consisting, briefly, of plants and structures, machinery, mains and miscellaneous adjuncts to such distribution system. The only division therefore to which forestation applies is land. The land of a water company, which in its greater part consists of its watershed, is usually rough woodland, and is charged in the investment account at its cost and so remains during its existence as a part of the water supply system, unless for very good reasons to the contrary, which must be the subject of consideration by the Public Utilities Commission exercising jurisdiction. When it was purchased, it was probably at the usual low price of woodland country, but in the years that have intervened since its purchase, and during the years of its control by the water company, nature has contributed to a tremendous increase in its value, not in the land itself, but in the growth of the timber upon it. A lapse of twenty, thirty, or forty years or more has brought about a change in the character of the growth on the watershed and the value of the wood thereon has increased many times the value of the property. The revenue which may be derived from the sale of lumber, telegraph and telephone poles, railroad ties and spars, without detriment to the watershed, probably exceeds in many instances the actual cost of the whole property at the time of the establishment of the water company. In regarding such revenue, it certainly would not be good accounting to credit the cost of the land or the capital investment with the proceeds of such sales, and thereby destroy the historical cost of the plant and equipment, for it is the rule of all public service accounting that the investment in plant and equipment be carried on its books at cost. It might occur that somewhere on the watershed there was discovered a valuable mineral vein or a ledge of highly desirable building material which, without detriment to the watershed, might be worked for a substantial profit. The income therefrom would not, and should

not, be credited to the original cost of the property. If, therefore, such unearned income should not be credited to its cost, then any cost for substituting trees, with the incidental expenses attending such process, should not be added to the cost of such property. In this event the costs of forestation are not costs chargeable to investment.

There may be one other division of accounts that might be suggested as proper for the cost and revenue of forestation, and this is under the head of "Expense and Revenue of Non-operating Physical Property." Upon reflection, however, it will be seen that this division of public service accounting would be entirely inappropriate for the purpose. Non-operating physical property is that property which has been acquired by a company, such as real estate or buildings, or similar property earning some revenue and subject to some expense. It may have been acquired as an investment or it may have come to the ownership of the company in connection with the acquisition of other property. At any rate it represents money invested by the company and is shown on the balance sheet as an asset. Such costs or revenue as there may be in connection with its ownership by the company should appear and be accounted for under "Non-operating Physical Property," as a gain or loss on such investment. It is the general practice to show this at the close of an accounting period, but in forestation there is no specific physical property on which there may have been a revenue or expense, except trees growing on land already capitalized and shown on the balance sheet. Forestation is the expense or revenue, according to the circumstances of the program carried on by the accounting company.

We have eliminated, therefore, costs of forestation as costs of operation and as costs applicable to increase in the investment in the plant and equipment of the company, but the company has spent money, perhaps large sums of money, in its forestation program, and it has received revenue in connection therewith. To what account shall such items of costs and revenue be debited and credited? They must be as carefully considered as any other items of expense and revenue and perhaps even more so. It is my contention that there should be set up on the books of the water company indicant accounts called "Forestation" and "Forestation Reserve" to the first of which all costs in connection with the program or policy of the company in this respect should be directly charged, and to the second all revenue received in connection therewith should be directly

credited. Forestation is so different from the ordinary operations of a water company that the accounting relative to it should be separate and distinct.

There seem to be certain good reasons for this suggestion. If the costs of forestation are charged to operating expenses, then this expense is transferred to the public through the prices charged for the service which the accounting company renders, while the revenue received, being no part of revenue derived from supplying water, contributes in no way to reducing the cost of the service of the company to the public. If the costs of forestation are charged to the plant and equipment account, and the revenue therefrom credited to such account, then you are destroying the historical cost of the investment as well as carrying on an operation account which may entail either a profit or a loss within the capital account. In either one of these cases, if costs and revenues are so treated, the actual amount from either side is lost sight of and absorbed in the general plant account, while, if it is treated in the way suggested, the actual cost and revenue is always readily available, and if the revenue therefrom should be, as it is quite likely to be, a considerable amount, it becomes a segregated surplus and not thrown into and lost in the general surplus account.

WATER WORKS MANAGEMENT[1]

By Chas. B. Burdick[2]

The city water works is one of the most important of local industries, either public or private. Without it the modern city cannot exist. Often it represents an investment fully as large as any other industry in the city. It requires large expenditures for operation, maintenance and new construction, and it offers the same opportunities for expert management as in enterprises of like magnitude in the commercial world.

The water works manager is confronted by nearly all the problems encountered in private enterprise. In addition he must deal with the public under a relation somewhat different in form from that of the merchant or manufacturer. It is the object of the present paper to refer to some of the broader aspects of water works management, which have occurred to the writer through association with a considerable number of water works properties, relating more particularly to the policies which underlie good service, rather than the executive details, in which the majority of water works managers are quite expert.

GROWING BUSINESS

The average American City doubles in population about once in twenty-three years. It is not financially practicable nor would it be economical to build water works capable of supplying indefinite future needs in the average city. The investment would be too large, and it would throw the burden too heavily upon the present water takers. It is better policy to build for the near future on a well defined plan capable of indefinite expansion, if possible. It is important that expenditures for betterments be carried out well in advance of needs, for a deficiency in water supply is likely to lead to heavy losses from fire, or, in an industrial city, a serious water shortage may result in losses to manufacturers and wage earners. If such shortage is persistent it may hamper the growth of the city.

[1]Read before the Iowa Section meeting, November 1, 1922.

[2]Of Alvord, Burdick and Howson, Engineers, Chicago, Ill.

Good management, therefore, requires that the available revenues of the property should be proportioned to a well defined program of construction. It is believed that this is the most important phase in water works management. More plants fail in good service today through inability to finance needed improvements than from any other cause. This condition usually arises from a failure to look sufficiently far into the future, or to provide funds a little in advance of need.

A PROGRAM OF IMPROVEMENT

While it is not practicable to build works for an indefinite future, it is perfectly practicable to forecast, with reasonable accuracy, service requirements and to place on paper the improvements that probably willl be needed over a generation or more, with estimates of cost. It is practicable to forecast the most probable growth of the city, the amount of water to be pumped, the area that must be supplied, and the size of the main pipes required for good service in fire protection now, ten years from now, or twenty years from now. It is practicable to investigate the source of water supply and to determine how far it may economically be developed, what future additional sources of water supply are available, and which are likely to be developed with greatest economy under future requirements. When the future requirements of service have been determined, it is comparatively simple to determine the number and size of engines and boilers, and the extent and direction of expenditures for housing them. The requirements for water storage may be forecasted with accuracy when the probable conditions of service are fixed and the most feasible plans for water supply have been determined.

Thus to formulate a program it is not necessary that the water works manager should be gifted with second sight. No magic is required for reasonably dependable forecasts. All that is required is that the program laid down shall be the best program possible in the light of past experience in the city in question and in similar cities. When the best program has been determined it should be followed by proper investments a little in advance of need. No water works should work on a margin less than three to five years in advance of its service requirements. If it is working on a well defined program, certain expenditures will be made necessarily further in advance, as in the purchase of lands or sometimes in constructing a portion of feeder mains.

It is not to be expected that the future may always be forecasted with accuracy. The program can and should be modified from year to year in the light of further experience. If the service requirements have been overestimated, improvements made will last somewhat longer than anticipated. If the service requirements have been underestimated, then the building program will be speeded up. But under adequate rates it is assumed that funds will be available more quickly, if the rates have been adjusted to fit a program of growth.

In the absence of a well defined program, improvements must be hurriedly conceived, financed and carried out. This results in abandoned pumping stations, because they are no longer capable of expansion, feeder mains taken up, because they are too small, water supplies abandoned, because they are too close to town, or no longer capable of expansion. In short, it means wasted money. It is true that good economy sometimes dictates the temporary use of structures later to be abandoned. If this can be shown to be good economy under local circumstances, no fault may be found with it, but it should be done under a good program carefully considered.

A GROWING INVESTMENT

The latest available United States census statistics, which refer to prewar conditions, indicate that the average investment in municipal water works is $32.60 per capita of the cities supplied. This refers to 105 cities in the United States, over 30,000 population, aggregating 19.6 million people. The average operating expense was $1.48 per capita. Allowing six per cent for interest on the investment, and one per cent for depreciation, the fixed charges would be $2.28, making the cost of water $3.76 per capita, including operation and fixed charges.

At the present time our works are operating upon a high scale of prices, although somewhat lower than those obtaining two years ago. Cast iron pipe, the largest item in water works construction, was worth about $25.00 per ton prewar at Chicago, $85.00 at the peak early in 1920, and about $49.00 at the present time, 100, 355 and 200 per cent respectively as compared with the prewar basis. Common labor, using 1915 as the 100 per cent basis increased to about 225 per cent upon the average, and has now receded to a little under 200 per cent. Other items entering into the cost of water works are, however, now upon a lower price basis, particularly

construction costs which were high and uncertain two years ago. Recent appraisals of several plants in detail indicate a total price basis approximating 160 as compared with 100 per cent prewar. Applying this ratio to the census figures indicates that at the present time new water works construction costs not less than $52.00 per capita.

The review of operating expenses presented by Mr. Leonard Metcalf, C.E., in a paper before this association published in September, 1922, indicates that the per capita operating expenses probably approximate 175 per cent at this time as compared with a 100 per cent prewar base, and, therefore, probably approximate in the neighborhood of $2.60 per capita per annum. Seven per cent to cover interest and depreciation on $52.00 per capita investment, is equivalent to $3.64, which, added to present operating expenses, makes the cost of water about $6.24 per capita, or approximately 170 per cent of the prewar figure.

On the present price basis, therefore, the average American city of 100,000 people must spend about $5,200,000 for new construction during the next twenty-three years. This is equivalent to about $225,000 per year. This expenditure will, of course, be more or less in individual cities, depending upon how fast they grow, how successfully they have looked ahead in planning the works already built, and the extent to which existing properties are necessarily abandoned. The city with the most successful building program will produce the cheapest water under ordinary circumstances.

DISTRIBUTION OF COST

When the probable service requirements of a city have been determined, and a building program has been laid down, it is then practicable to prepare an estimate of operating expenses, allowances for depreciation, and the annual sums required for betterments. When this has been done, it is practicable to determine the probable cost of water from year to year, and to fix water rates that will operate and maintain the property and finance the necessary improvements. A successful rate is one that maintains the property and equitably distributes the tax between those receiving service.

In the formulation of a system of rates, a reasonable period in the future should be considered, say, ten or fifteen years, for rates are not easily changed. In the light of the water works program the total sum to be derived may be determined. This sum should first be

divided as between the public in general that receives fire protection, and the public and private water takers. A large part of the ordinary water works investment is necessitated by the requirements for fire protection. There is no reason why the public-at-large should not carry this investment. It also affects operating expenses in less degree. That part of the revenue to be derived from the water consumers should be distributed among the different classes of rate payers, reasonably in proportion to services rendered. If possible a rate should be fixed for very large users low enough to secure the business. This is impossible in some cases, for water cannot be continuously sold at a net loss, but it is sometimes practicable to supply the large consumers at less than the average cost of the water, including all the fixed charges, and by so doing actually reduce the water bill of the small consumer.

WATER BOARDS

The management of a municipal water works directly through the City Council or City Commissioners has been extensively practiced, and, in general, it has proved a failure. A permanent policy is just as necessary in a water works as in any private business. It should have a management as permanent as is possible in public undertakings. No program can be laid down and successfully followed under periodic changes in management. Most city administrations change several times in a decade. Where Council management has worked satisfactorily, you will usually find a water works superintendent big enough and capable enough to hold his job in the face of political upheaval. Usually, however, he must be somewhat of a politician to accomplish this.

It is believed that the best form of water works administration today for municipal plants is through a Board of Trustees with moderately long overlapping terms, so created and constituted, as to be removed from politics as far as possible.

At Des Moines, Iowa, the plant is administered by five Trustees appointed by the Mayor and Council. The terms are overlapping. The Board at present consists of the president of an insurance company, the manager of a large department store, a coal operator, a former mayor and a representative of union labor. The plant is operated in all respects in the same way as a high-grade private corporation. The expenditure of funds is entirely in the hands of

the Trustees. Bond issues must be approved by the City Council. The works, however, will largely be financed out of revenues.

About twenty years ago the city of Burlington, Iowa, inaugurated a water works administration, in the acquirement of a private plant, that has operated very satisfactorily. A local corporation was formed which purchased the city water works from its former owners. The necessary capital was obtained by the sale of 4 per cent bonds and 6 per cent stock. The property is administered by five Trustees, three appointed by the stockholders and two appointed by the City Council. All profits above 6 per cent on stock go to the city and are to be applied in the purchase of stock. Ultimately the city will own a majority of the stock.

At Orlando, Florida, a new departure has been taken in the method of appointing the water works trustees. The Mayor named as the water board the presidents of four local banks. It is planned to incorporate this automatic system of appointment in the state law, relating to this city and thus keep the water works out of politics permanently.

A continuing policy, a well considered program of betterment and an adequate system of rates are the fundamentals of success in the water works business. Given these, the manager may organize his executive duties, administer his property with economy, and go to bed at night with reasonable assurance of unbroken rest.

STREAM POLLUTION MEASURED IN TERMS OF SANITARY QUALITY OF DRINKING WATER

By Russell Suter[1]

Problems involved in State control and regulation of stream pollution and the use of water from streams for public supplies may best be studied by constructing a "quality profile" of the stream. Such profile requires the adoption of a unit of measurement common to all the numerous factors involved and which, further, can be interpreted in terms of sanitary quality of drinking water. It seems that in some cases the logarithm of the colon count of the water may be used as such a unit. Suggestions as to the use of this unit are here made, illustrated by a theoretical quality profile of the Hudson and Mohawk rivers (fig. 2). An attempt is made to evaluate the phenomenon of "self-purification" as an aid to combating the popular misconception as to the rapidity of that process.

THE COLON COUNT—A COMMON MEASURE OF POLLUTION PHENOMENA

Waterworks men are chiefly interested in pollution by sewage. From this viewpoint the chief factors affecting the quality of the raw water are:

Volume and concentration of sewage
Volume of stream flow
Current velocity in stream
Natural and artificial purification

That all these factors affect the colon count of the water has been shown by various authorities. The results are here restated.

Colon bacilli are always present in domestic sewage, the total number is proportional to the contributing population (1), but the number varies with the season (2), corresponding apparently to a seasonal physiological change in man (3). As a working average, it may be assumed that 100 gallons per capita per day of fresh un-

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treated sewage contains 10,000,000 B. coli per 100 cc. By the use of the colon count, uncertainties resulting from different strengths of sewage or rates of water consumption are eliminated.

In a large drainage area it seems safe to assume that the sewage contributing population is the same as the population supplied with water from public systems.

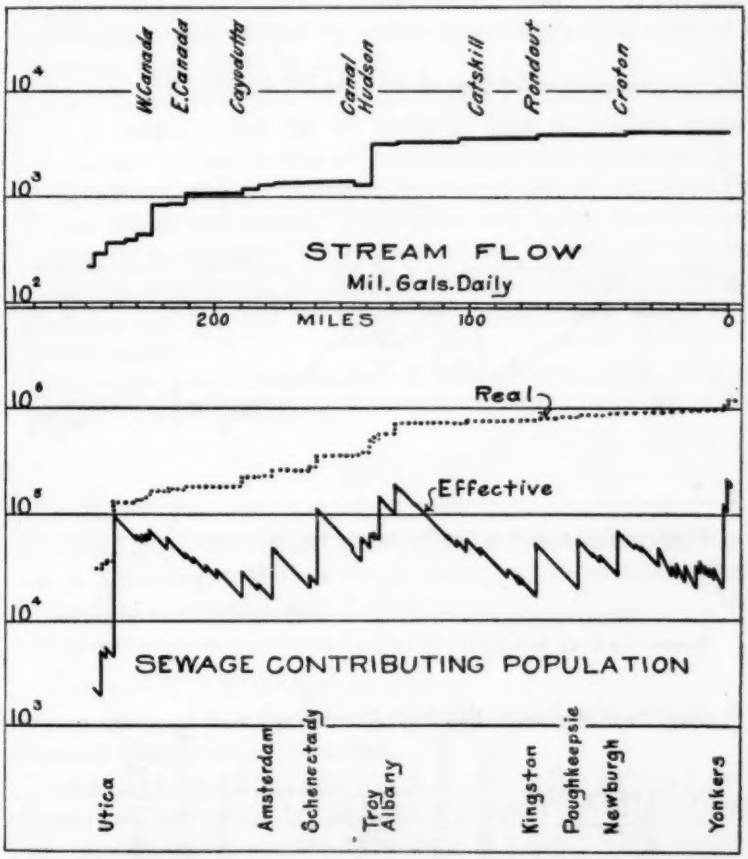

FIG. 1. MOHAWK AND HUDSON RIVERS—FLOW AND SEWAGE POLLUTION

Sewage discharged into a stream eventually becomes diluted in proportion to the volume of flow of the stream. If dilution is immediate and uniform the resultant count will vary directly as the population and inversely as the streamflow (4). Such dilution is seldom found and error of some magnitude results from the assumption that it takes place, as is here done.

Current velocity affects the time factor and therefore the rate of natural purification. Usually mean current velocities have to be used in spite of the evident errors resulting from such practice. These errors are of greatest magnitude in tidal streams. They are the most uncertain factor in this problem.

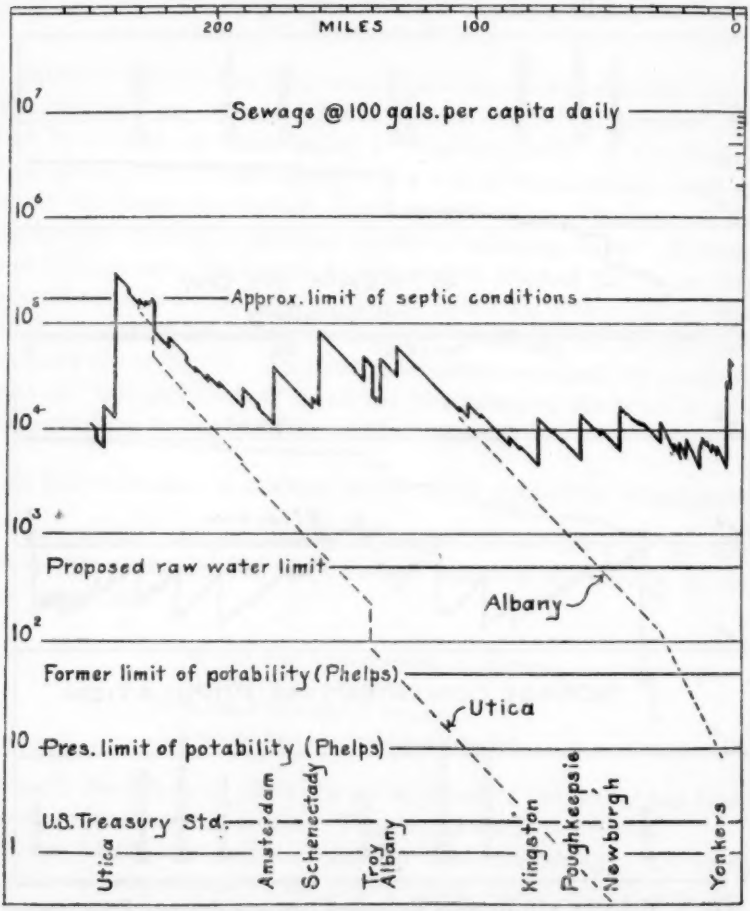

FIG. 2. MOHAWK AND HUDSON RIVERS—COLON COUNT PER 100 CC.

Efficiency of sewage purification can be measured by the reduction in the colon count, but, as such counts are of minor value in the regulation of most sewage treatment plants, accurate data are lacking, particularly for the less complete installations. In this study it has been assumed that Imhoff tank treatment reduces the

colon count by 40 per cent. As such plants are few on the Hudson and Mohawk, accurate determination of this figure was not important, but it would be vital for some studies.

Natural or self purification of a sewage polluted stream is primarily a function of time and therefore of current velocity. The law below derived probably applies more nearly to settled than to raw sewage, but the error is small and on the safe side. The rate of purification is also affected by temperature, but no evaluation of this important effect could be found.

Colon bacilli exposed to the unfavorable environment of a stream cease to multiply and die off, probably from starvation, exposure and old age. Their pathogenic compatriots, such as typhoid bacilli, are similarly, but more quickly, affected. It follows that mere lapse of time causes real sanitary purification and that, if this decrease in pathogenic potentiality is measured by the reduction in the colon count, the results will be on the safe side. This self purification effect is a real one, but has always been given undue weight by the general public.

Phelps has formulated the law of decrease of bacteria under such circumstances (5) as follows:

$$\log \frac{N_1}{N_2} = KT$$

in which N_1 is the original count, N_2 the count after the time T, and K a constant. If N_2 is the percentage of forms remaining after T days, this equation may be written

$$\log N_2 = 2 - K\,T$$

It is understood that Phelps obtained this equation by a study of the effect of disinfectants on bacteria.

A study of the rate of decrease of B. coli in the waters of the Potomac has been made by the United States Public Health Service (5). In the report on that work there is a curve which shows the rate of such decrease in terms of time. The points from which this curve was derived are shown on figure 3. No discussion of the curve is given in the report, nor is any attempt made to reconcile the evident difference between the curve and Phelps' law. On semi-logarithmic paper Phelps' law plots as a straight line, like that on the left, whereas the points define a curve which tends to become stabilized after about thirty days.

Infection from and location of lower outfall sewers, temperature and stream volume were neglected in plotting this curve. Coli from sewers, shipping and surface wash enter the Potomac below Washington and the river could not be free from them even though the sewage of the city were to be diverted from it. The count of 40 per 100 cc. indicated by the stable portion of the curve is a reasonable one for such "residual" pollution. Assuming this residual, two outfalls and Phelps' law, a curve can be constructed which fits the observed points more closely than the published curve. Certainly for the high values and probably wholly, therefore, the law may be justified from these data.

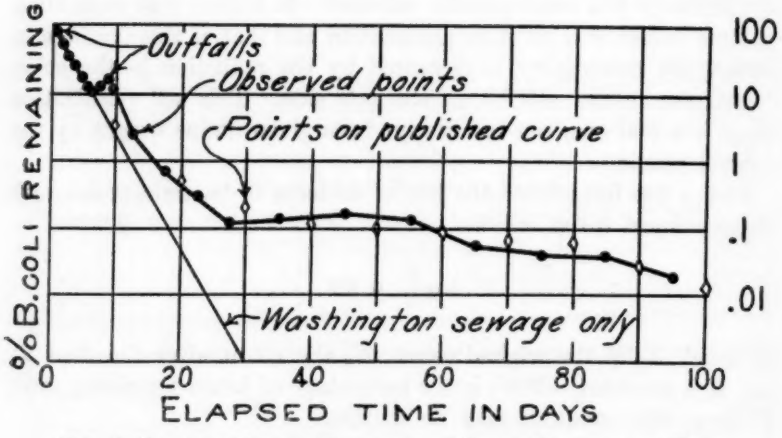

FIG. 3. POTOMAC RIVER—DECREASE OF COLON COUNT WITH TIME

More detailed study of published data shows that, neglecting temperature variations, Phelps' law for the Potomac may be written

$$\log N_2 = 2 - 0.2\,T$$

This value of K corresponds to a reduction to 10 per cent of the original figure at the end of each five day period. In plotting the Hudson river curve this value was used.

Plotting of the quality profile is facilitated by the use of semi-log paper and graphical methods. As population and B. coli are proportional, it is simpler to use the census figures directly. Starting with the water supplied community farthest upstream, the population of that place is plotted as an ordinate on the proper distance point.

The pollution due to this place at a point downstream from it can be found by drawing through this point a straight line having a slope dependent on Phelps' law and current velocity—this line gives the "effective population" at the lower point. This effective population at the second community is read, increased by the actual population of the second place and the sum plotted as the "effective" population at the lower place. The process is repeated until a complete curve of effective population is constructed (fig. 1).

Such a curve shows the total number of B. coli at any point of the stream. To obtain the count it is necessary to introduce the factor of dilution by dividing total bacteria by volume of streamflow. A curve of streamflow—in millions of gallons per day—may be plotted on the same sheet and the division accomplished by subtracting—with dividers—the ordinates of the second curve from those of the first. The resultant curve will give colon counts. A scale for it must be determined from the relation:

100 gallons sewage per capita per day contains 10,000,000 B. coli per 100 cc.

THE COLON INDEX—A MEASURE OF WATER QUALITY

To be of use, values from the curve above derived must be interpreted in terms of water quality. It has been assumed, for reasons given below, that:

The logarithm of the number of B. coli per 100 cc. (the colon index) is a reasonably fair measure of the relative sanitary quality of the water.

On that assumption figure 2 gives a reasonably accurate picture of the variations in sanitary quality of the water of the Hudson.

Whipple (6) gives a table for the interpretation of the presumptive test for B. coli, which is representative of current practice. It may be written thus:

SANITARY QUALITY	TEST	COLON COUNT PER 100 CC.	COLON INDEX
Safe	+ in 100.0 cc.	1	0
Reasonably safe	+ in 10.0 cc.	10	1
Questionable	+ in 1.0 cc.	100	2
Probably unsafe	+ in 0.1 cc.	1000	3
Unsafe	+ in 0.01 cc.	10000	4

It will be seen that each successive step in the quality scale corresponds to a division of the count by 10, or a decrease in the logarithm

of the count by 1, that is the quality is measured inversely by the logarithm of the count.

Actually our scale for water quality is the typhoid death rate. It would be idle to attempt to write an equation expressing the relation between death rate and count, but they go up and down together. Water which will pass Treasury standard (2 B. coli per 100 cc.) should be accompanied by a death rate from water borne typhoid not higher than 2 per 100,000. Past experience with Albany water (20,000 B. coli per 100 cc.) would indicate that, if purification were given up, the death rate might be over 100 per 100,000. The relation between these figures is shown by the table below.

	COLON COUNT PER 100 CC.	TYPHOID DEATH RATE PER 100,000	LOG COLON COUNT PER 100 CC.
Raw water	20,000	100	4.3
Treated water	2	2	0.3
Residual percentage	0.01	2.0	7.0

The change in the logarithm of the colon count is of the same order of magnitude as the change in the death rate, while the change in the actual count is of a very different order. This again suggests that the logarithmic count is a reasonably good indicator of the sanitary quality of the water.

There would be no object in evolving a fine-spun theory as to why this is so. It is not improbable that Mr. Napier did the world a disservice when he named logarithms what he did. In this case there is neither magic nor mystery about them. A range of colon counts running from unity to 100,000,000 is to be compared with a range of death rates expressed by figures between unity and 200, or quality "steps" of which half a dozen are fairly sufficient. It seems evident that the actual digits in the count are of little value, the important question is merely the position of the decimal point or order of magnitude of the count, whether it is expressed in tens or tens of thousand. Briggs logarithms are merely a refined method of expressing this and hence happen to be useful in this connection.

As present practice in water analysis seldom gives data from which the colon count can be determined, it has been impossible to check this Hudson river curve elsewhere than at Albany. At that point the calculated count is 30,000, whereas the actual count for the assumed condition as to streamflow is 20,000. The logarithms of

these counts check within 4 per cent—no such degree of accuracy is claimed. No attempt has been made to show the "residual" pollution—the Potomac results indicate that it would be too small to affect results in this case.

APPLICATIONS

On this scale of quality, one large division of the vertical scale corresponds to the multiplication or division of the count or the dilution by 10. To improve the quality of the water by the amount represented by one such division requires a purification process of 90 per cent efficiency; by two divisions, 99 per cent efficiency, and so on. Thus, to give water which will pass Treasury standard, the Albany filter plant must have a bacterial efficiency of at least 99.99 per cent. Study of efficiencies of purifiation plants will enable those portions of the stream which are suitable sources of supply to be determined.

Study of this curve throws light on the vexed question of self purification. It is evident that a stream once heavily polluted cannot be expected, under ordinary circumstances, again to be a fit source of unpurified drinking water. In fact the real question to be answered is "Is this water fit to filter?"not " Is it fit to drink?"

By Phelps' law an actual population of 1,000,000 persons will be reduced to an "effective" population of 1 person in thirty days, but will still amount to 100 persons at the end of twenty days. This confirms Mason's statement (7) that thirty days storage is in many respects equivalent to filtration; but also shows how little "short circuiting" of a reservoir is necessary to render storage invalid as a means of purification.

In computing the quality profile for any river, it is necessary to assume some particular hydraulic condition of the river. The Hudson river curves on figure 1 were computed for normal low water flow—that rate of flow which has been exceeded for 80 per cent of the time. For any other rate the curve would be different.

From such a quality curve the effect on a raw water of the treatment of the sewage of an upstream community can be computed. Phelps' law enables allocation of the responsibility for the colon pollution existing at a given point to be made to the various communities contributing that pollution to the stream (fig. 4 and following table).

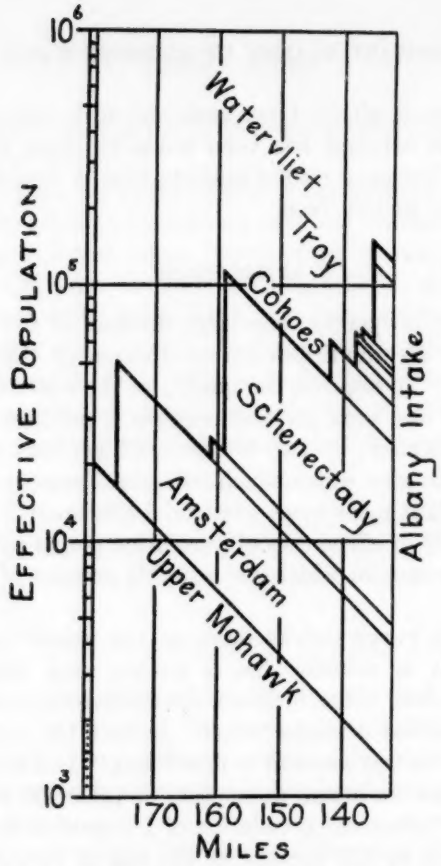

FIG. 4. MOHAWK AND HUDSON RIVERS—ORIGIN OF B. COLI AT ALBANY

Origin of sewage pollution at Albany intake

PLACE	EFFECTIVE POPULATION		PERCENTAGE OF TOTAL INDIVIDUAL
	Cumulative	Individual	
Watervliet	124,000	13,000	10.5
Troy	111,000	61,000	49.1
Green Island	50,000	3,900	3.1
Waterford	46,100	3,800	3.1
Mechanicville	42,300	2,800	2.3
Upper Hudson river	39,500	5,500	4.4
Cohoes	34,000	10,000	8.1
Schenectady	24,000	19,400	15.7
Scotia	4,600	700	0.6
Amsterdam	3,900	2,600	2.1
Upper Mohawk river	1,300	1,300	1.0
Totals		124,000	100.0

It is not claimed that this method will solve all questions with regard to stream pollution and water quality, or even finally solve any one of them. Probably no single measure of water quality should ever be used and in some cases the colon count is of least importance. Neither is it claimed that any of the evaluations herein are final—most of them are based on incomplete or insufficient data and further study will be required to establish them. It is thought that this method or some modification of it will enable the results of stream quality studies and questions of State control of the use of streams to be presented in an orderly and useful way which will make them of greater service to waterworks men.

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COMBUSTION OF COAL IN BOILER FURNACES[1]

By M'Kean Maffitt[2]

In the average boiler plant of today too little thought is given to obtainable efficiencies and necessary economies. No matter how small a plant may be, fuel economies are worth striving for. A dollar spent for apparatus or labor that will save a dollar's worth of coal is a dollar well spent.

In every water works plant there is a check on the cashier. He must account for every cent that he receives. How many nights have you known your cashier to sit up half of the night and look for that penny, or dollar, that he was out of balance? How many nights have you sat up looking for that one or one hundred tons of coal that your boiler plant was out of balance? Why pay more attention to money in the shape of paper or silver than you pay to it in the shape of coal?

If your town is one hundred per cent metered, you have paid $15.00 or more on each service so that you might have a meter there to see how much water that particular consumer gets. You pay an auditor to check up the cashier to see that he accounts for every cent that he receives and that he collects all that he should collect. Yet you pay a man to take a scoop, the bigger the better, and throw gold dollars, in the shape of coal, into the fire and burn them up and never is a check made to see if he burns them correctly or incorrectly. As long as he keeps steam in the boilers so that the pumps will not stop that is about all you expect of him. No matter how he does it, steam must be kept up and nothing much is said about it. If the steam goes down then you go to the boiler room and order the fireman to throw more coal to the boilers. If you would study your boiler room and furnaces and mix a little common sense with the coal, your steam pressure would go up and your coal bills would come down.

Now let us take a shovel full of coal, say 20 pounds, and see what we should get, and what we do get, out of it.

[1] Presented before the North Carolina Section meeting, November 14, 1922.

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Twenty pounds of good Pocahontas coal equal 270,000 heat units. One heat unit equals 778 foot pounds of energy. Therefore, one shovel full of coal equals 210,060,000 foot pounds of energy or 100,000 gallons of water pumped against a head of 250 feet. That is absolute perfection. But as we can not even approximate perfection, we lose in efficiency at every step. We lose when we burn the coal under the boiler, when the heat is absorbed into the boiler, when the steam passes to the steam end of the pump, when the steam end of the pump runs the water end of the pump and when the water end of the pump delivers the water. In fact we lose everywhere, until at Wilmington, we get for that 20 pounds of coal not 100,000 but merely 4,000 gallons of water, or only four per cent of the power originally in the coal.

All of these losses are not in the furnace and we shall not treat of them here. We shall discuss only those in the furnace that are preventable. Such losses as are not preventable will be passed by.

If we consider one shovelful of coal as pure carbon, which will require 11.5 pounds of air per pound of carbon for perfect combustion into carbon dioxide, we have a demand for 230 pounds or 3066 cu. ft. of air at atmospheric pressure and 70° Farenheit temperature. This amount of air must be equally and uniformly distributed over and through the coal when it is burning. If it were all applied at once, and could instantaneously unite with the coal, we would have an explosion that would wreck the plant. It must be applied at the proper time, rate and place or we get poor results. Most, if not all, should go through the fuel bed. This depends on the thickness of fuel on the grates. If the fuel is too thin it should all go through the bed. If the fuel is too thick, some of it should go in over the fuel bed. But as this is rather a difficult proposition, it is better by far to have the fuel bed the proper thickness so that all of it may go through the bed and do its proper work. If the fuel bed is a little too thick, some of the air should be let in over the fire, but just enough to burn those gases that are distilled immediately after green coal is thrown onto the fire. As this is a delicate adjustment, one should be careful of it and have the best known methods of admitting this air over the fire, so that immediately the excess gases are consumed this over-fire air may be shut off and all the air passed through the fuel bed.

The air that goes through the fuel bed should be equally and evenly distributed throughout the whole mass of fuel. There should

be no bright places (blow holes) or dull spots (thick places). Where there are bright places, the fuel is too thin and too much air is getting in and this air simply tends to cool the fire. Where there are black or dark spots, not enough air is getting in and you are making carbon monoxide.

Your fireman knows that if he leaves the fire doors open he will not get any steam, because his fire will be cooled down so fast that it will not be hot enough. But does he stop to think that several little bright spots may let in enough air to equal the amount let in through one fire door? In either case he gets too much air, at the wrong place, and the coal pile suffers. He burns more coal to deliver the same amount of heat to the boiler.

He also knows that if he shuts off the draft he can not keep up the steam pressure because his fire will not burn fast enough. If he has several dark spots in his furnace they may be shutting off as much draft as one fire door will shut off. In either case the coal pile suffers, because he is making carbon monoxide and not carbon dioxide.

Take each pound of that shovel full and burn it with the proper amount of air at the right time and place and you get carbon dioxide as a result and 14,544 heat units ready to go into the water in the boiler. Take the same pounds of coal and burn them with the doors shut tightly or with the fire choked down with too much coal, and out of each pound of carbon you will get carbon monoxide and only 4351 heat units, a loss of 10,193 heat units or 70 per cent.

We can not get perfection in our work, nor do we need to take the very least work offered, but there is a happy medium some where that all of us may reach. All of us who go above that happy medium are working towards greater efficiency.

The best results are obtainable with a little too much air rather than with a little less than necessary. Just about 40 or 50 per cent too much air will give the best results obtainable in good practice. Joseph W. Hays states in "How to Get More Power From Coal." "The average power plant uses about 300 per cent too much air." Three hundred per cent too much air will give you about five per cent carbon dioxide and will mean that you have a preventable fuel loss of 25 per cent. *Preventable loss* means that you can *prevent* it and prevent it right now. For three whole months of the year you will not have to buy a pound of coal. Your whole plant will be run by the carbon monoxide, foundry gas, that you are now making and throwing away in your boiler plant.

To prevent this loss we must add to the coal a little gray matter, or common sense, and nothing else; not even some of the so-called fuel savers or chemicals that burn ashes. We must get the air to the fire just when and where we want it. We must have the fire so arranged that all of that air will be used. The carbon will take all of the air it needs and no more. If we are going to let it run through the walls of the furnace and through holes in the fire and cool the gases so that we can not get enough heat out of them, why not open the fire doors and cool down the whole outfit?

Unless I am much mistaken, air enters the furnace at too many places right now. I can take the average boiler plant, let the regular fireman fire the boilers, take a little waste, putty and cement, a candle and some good boiler wall covering and, in less than two hours, have that boiler popping off so much that the fireman will think that his steam gage or pop valve is out of order.

Hold the candle flame near the walls and watch the draft draw it into the cracks. Ram the waste and putty or cement into the crack. Go over every square inch of the setting like that and then plaster the whole thing over with a good boiler wall covering and I venture to say that at the very least you will save 5 per cent of your fuel.

Suppose now that your boiler walls are tight and you are still getting a low percentage of carbon dioxide. The chances are that your fire is so thin or irregular that there is about 200 per cent excess air getting in through the fire bed. Fill up those holes or bright spots and level the bed down until it is about four inches thick, not including ashes and clinkers. Four inches of fuel, not over five at the most, is the proper thickness of fuel bed. When you get the fire to this thickness take another carbon dioxide sample and it will have gone to 10 per cent or over. Your preventable fuel losses then will be only about six or eight per cent.

The best thickness of fuel bed that I have ever found is between four and five inches, perfectly smooth and free from either bright or dark spots. With this thickness of fuel; fire lightly, and often. Scatter the coal well over the whole fuel bed, unless there be bright spots developing. These must be filled, and you will have a fire of maximum efficiency.

If you will always get the same grade of fuel, determine the proper thickness of fuel bed for that grade, keep the fuel bed free of holes or thick places, keep the furnace walls tight, let in the air above the

fire for only a little time after firing, fire evenly and often, you may keep your carbon dioxide readings around 10 or 11 per cent, reduce your excess air to less than 100 per cent, and your preventable fuel losses to less than 8 per cent. All the equipment necessary is an orsat at about $40.00. If you add to the orsat a few draft gages, automatic draft and feed water regulators and several good thermometers you may reduce still further your losses and save coal.

Take the orsat and get a few flue gas analyses. Take a sample and then look at the fire. Try another one and observe the difference in the fire and in the sample. If your percentage of carbon dioxide is low, see if the fire is not too thin or if it has any bright spots in it. Build up the fire a little and fill up the holes with live coals or with fresh fuel and then take another sample of gas. Observe the difference. The fire will be brighter all over, the percentage of carbon dioxide will immediately show an increase and the preventable fuel loss will show a decrease. Keep trying this arrangement until you get the correct index on the fire bed when governed by the carbon dioxide readings. Do not make the readings for just one day and then sit down and a wait results, but make them every day. Take the fireman with you. Show him what it means to the coal pile to have the fire just right. Let him see that you have a check on him and can tell just how he is taking care of his fire. In about three months the coal dealer will call up to ask when you put on central station power. He will think that you have stopped the use of coal, your fuel bills will be so little.

Another bad leak of fuel is in the cleaning and raking of the fires, and in the shaking of the grates in the type of grate built for that purpose. Hays says that four percent of the carbon is wasted in the ash when cleaning fires. Take that shovel full of coal, twenty pounds, and throw four percent or about one pound of it in the ash pile. That is what you are doing every day in the average boiler plant. If your grate openings are too large, if your fireman rakes the fire too freely, if he overloads the fire bed on shaking grates and then runs the fire down through the grates, if he takes a slash bar and turns the ash up on top of the fuel bed he is wasting coal, both in the ash and in the way that he burns what is left in the furnace. Go home to your ash pile and take a few shovels full of ashes and clinkers and wash them down with water. Take each lump left and examine it closely. Put each clinker to one side and each piece of coke to the other side. Then sit there and look at what is being thrown away every time your fires are cleaned.

I know that it is some job to stand in front of a boiler and clean out the fire, because I have done it. It takes a man to stand it. Hang a couple of hooks in front of your boiler. Hang a piece of pipe, with a trace chain curtain on it, on these hooks in front of the furnace door. Insert the fire cleaning tools through this chain curtain and you can stand there and clean the fire better than you could otherwise and not get half of the heat in your face. The chain curtain holds the heat in the furnace, yet it allows sufficient visability and freedom for the fireman to clean properly his fires.

Perhaps you think that, if your boiler shell is down in the fire, you are getting good results, because your boiler is so near the fire. You are not. That boiler shell acts like a dash of cold water on the fire. It cools the gases so quickly they can not burn.

If your steam pressure is 100 pounds gauge, your temperature in the boiler is about 338 degrees. If you have done all the things that I have suggested your furnace temperature is about 2,200 degrees. That boiler shell is colder to that fire than the North Pole is to the Equator. The difference of 1862 degrees, or six hundred percent, makes such a reduction in the flue gas temperature that it is simply impossible to burn them to anything but gas foundry gas.

The ignition temperature of carbon is 766 degrees, carbon monoxide 1210 degrees, hydrogen 1130 degrees, hydro-carbons 900 to 1200 degrees: all are above the temperature of the boiler shell. Now suppose that there is 25 per-cent volatile matter, or gas, in your coal. This volatile matter in distilled off immediately the coal is fired and you must have a furnace temperature sufficient to ignite it and space enough in which to burn it. Otherwise you lose it up the stack. If this volatile matter is hydrogen, or hydro-carbons, it has a high heat value, especially the hydrogen (50,000 to 60,000 heat units per pound) and it must be burned above the fuel bed. How can you retain it at a temperature of from 900 to 1200 hundred degrees when it is in contact with a boiler shell that is only 338 degrees. It simply is not burned, but it passes up the stack as smoke.

Did you ever notice a lump of coal spit a stream of smoke until a flame was put near it, when it immediately ignited and burned like a regular gas jet. That same little stream of smoke or gas multiplied a million times is the stream of smoke you see coming from so many stacks. If all the air leaks are stopped, the boiler shell raised high enough above the fire, the fire carried at the right thickness and not fired too heavily, that smoke will stop and all that heat value will be added to the bank account.

SPECIAL FEATURES OF RECENT FILTER PLANT DESIGN[1]

By Paul Hansen[2]

Since rapid sand filtration has become accepted as an economical and efficient method of water purification there has developed a tendency toward over-standardization. That is to say, too many of the details are regarded as definitely settled and perfected and engineers and filter companies are not always as alert as they should be to possible improvements or to the adjustment of design to the particular water to be handled or to the particular place where the plant is to be built.

Improvements are as a matter of fact being made and these should have due recognition, but there is lacking the same eagerness that was apparent about fifteen to twenty years ago. Perhaps the discouragement lies in the fact that, with the present development of rapid sand filtration, further improvement must be looked for in the refinement of details rather than in changes of a striking or radical nature and this in turn may make lack of progress more apparent than real.

The object of this paper is to stimulate a little thought along the lines of filter design improvement by describing a few efforts in recent experience, principally our own, and perhaps to throw out a few suggestions.

In some recent designs of relatively small filter plants ranging in size from 500,000 gallons per day to 4,000,000 gallons per day, we have kept in mind especially the securing of operating economies. In all of these cases we have so coordinated the design with the pumping station as to enable the pump attendants to operate the filters. In the case of a small plant at Harrodsburg, Ky., it will be possible for one man per shift to operate the entire waterworks. This is made possible by the installation of an electric equipment which will carry the ordinary load. The old steam pumping equipment will be retained as a standby. Should it be necessary

[1] Presented before the Illinois Section meeting, March 30, 1922.

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at any time to operate the steam pumping equipment for any length of time, it may be necessary to hire extra labor for firing the boiler.

At Whiting and Winnetka, the pumping equipment has been made accessible to the filter plant so that on the night shift it will not be necessary to have a special filter attendant. These plants are of sufficient size to warrant the employment of one filter attendant on each of the two day-time shifts. It will be noted that in the Winnetka plant a small tunnel was built to give free access between the filter plant and the pumping station. This tunnel also has the additional mêrit of providing a gallery for water and steam pipes and electric conduits in a manner to give them free accessibility.

Economy effected in our recent designs for small plants is obtained through the relative arrangement of reaction chamber, sedimentation basins and filters. In a 600,000 gallon per day plant, as that at Harrodsburg, and a 3,000,000 gallon per day plant as at Winnetka, it is feasible to place the coagulating basins opposite the filters in such manner that all of the piping for the entire filter plant may be placed within a single pipe gallery. This materially reduces the tonnage of cast iron pipe required. It is difficult to express the exact saving made in this way, but in round numbers the arrangement effects a saving of about 10 per cent on tonnage of cast iron pipe as compared with several less compact layouts originally considered. Not only has this arrangement the merit of economy, but it greatly simplifies operation, inasmuch as the filter operator must take only few steps to reach any controlling valve in the entire plant. The arrangement also brings one end of the coagulating basins and the reaction chamber within the filter superstructure, so that the operator may with the greatest possible ease observe the effect of coagulation. A further economy in this arrangement is the reduction of the size of superstructure required for the plant.

The pipe galleries have been designed to give a free passage from end to end with ample head room. This is of great value in making accessible the numerous pipes and valves used in connection with the filters and sedimentation basins and also in giving access to the filter rate controllers for repairs and adjustments. The value and economy of a clear pipe gallery may be fully appreciated only by those who know the difficulty of taking out a pipe, repacking or repairing a valve or taking apart a rate controller in a crowded pipe gallery of the old type.

The free passage through the pipe gallery not only represents economy through giving greater accessibility to the complex piping, but actually represents a saving in pipe. This has been accomplished largely through the use of a single four-way specially designed casting at the lower filter opening. This incidentally is the only specially designed casting in the whole pipe gallery. All the other specials are standard.

There can be little argument as to the advantage of light in filter plants. As a matter of fact, this has often been neglected in most designs so that many parts of the plant, more particularly the pipe gallery, have been dependent upon artificial light. Moreover the crowded condition of pipe galleries and other parts due to a multiplicity of piping has prevented a proper dissemination of light. In designs for recent plants, special consideration has been given to the matter of having a flood of light in all parts of the plant that should be readily accessible for inspection and repairs, as the pipe gallery and filters. Economy of light is difficult to estimate in dollars and cents, but there is little room for doubt that laborers working on piping and valves and dependent upon imperfect artificial light are seriously handicapped and inevitably work more slowly. A measurable portion of their time is taken up in adjusting and shifting extension lamps so as to get a clear view of their work. The most serious objection to lack of light, however, is that the dark places are invariably neglected. Leaks and breakages go unattended and cleanliness is generally ignored.

It is important to give careful consideration to the arrangement of chemical preparation and feed devices. The main consideration is to have them so readily accessible that the attendant will have no excuse for neglecting their proper operation. In the larger plants we have found it desirable to arrange for the preparation of chemicals on a second floor and also to provide space at this point for the storage of chemicals. This is typical of the Winnetka and the Whiting plants. This arrangement facilitates dissolving and mixing the chemicals or discharging the chemicals into a dry feed machine, notwithstanding the fact that this places some of the operations on another floor. In the small plants, however, as at Harrodsburg, it has been found practicable to place the entire chemical preparation and feed devices within the operating room. In all cases, to facilitate the hoisting of chemicals, some form of elevator is used. In the case of Whiting and Winnetka, the elevator may

carry freight and passengers. In Harrodsburg, a small lift will be used which will consist either of some form of block and tackle arrangement or of dumb waiter. In all of the plants it is easily possible for the filter operator to handle the chemical feed devices, though during periods when consignments of chemicals are received, one or two laborers will be required to help place the chemicals in the storage space.

In all cases the chlorine apparatus and the laboratory are placed in close proximity to all of the filter operations. At Whiting and Harrodsburg they are on the same floor and within but a step or two of the operating devices. At Winnetka, it was found necessary to place the laboratory on the second floor adjoining the storage space for chemicals. While not ideal, this arrangement is not believed to involve any material disadvantages.

In the Whiting and Winnetka plants the filters have been equipped with hydraulically operated valves inasmuch as this is warranted where four or more filters are used and on account of the larger size of the valves. Hand operation would take considerable time and considerable effort. In the small plants, however, as Harrodsburg, with only two filter units of small size, hand operation is entirely practicable and, of course, represents an economy in first cost.

In the foregoing we have discussed primarily those matters which have a relation to economies in operating attendance, maintenance, upkeep and fixed charges. It is important, however, to remember that sedimentation basins must be designed with careful regard to the character of the water to reduce to a minimum the amount of chemical treatment required. The cost of chemicals is a considerable item in filter operation, generally amounting to something like 30 per cent of the total operating costs at a small installation and perhaps much more than this in the case of larger plants. It may often pay to install larger sedimentation basins, even though this involves an increase in the first cost, provided it can be demonstrated that the reduction in operating costs will represent a net reduction in total annual costs. It is significant that the modern tendency is toward larger sedimentation basins.

Another possibility for saving alum is the selection of a proper size of sand. A relatively fine sand with certain types of water may permit a material reduction of alum and effect net economies even with shorter filter runs and more wash water.

At Sacramento studies indicated an economy of stirring devices in reaction chambers as compared with baffles. It was found feasible also to use larger and fewer pipes in the underdrain system than is ordinarily done in practice.

There is an opportunity to effect real economies on total annual costs by providing a proper storage of filtered water. If sufficient storage is not provided, it means that the filters must be operated beyond their normal capacity, which will require additional quantities of coagulant and larger quantities of wash water for the filters. More serious, however, is the danger of delivering an imperfectly filtered and sterilized water when the filters are operated materially above their nominal capacity.

The aerators used at Whiting and Harrodsburg consist essentially of a shallow concrete basin or tray with floor sloped toward an outlet. The water is pumped to the aerator through a suitable grid of pipe with spray nozzles attached. These spray nozzles are of types commonly used for cooling condenser water and are designed to break the water up into a mist. To prevent the spray from being blown about by the wind, the aerator is surrounded by a wooden fence with side boards arranged like shutter slats, to provide free movement of air while causing the spray to be thrown back into the aerator. Nozzles used by us are of the so-called Spraco type. The accompanying table shows characteristics for various sizes and makes of nozzles.

The number of nozzles used per million gallons depends upon the size of the nozzles and the pressure behind the nozzle. We use a nozzle which, with a pressure of about 8 pounds, requires 12 nozzles per million gallons. We find that there is ample room for an aerator on top of the coagulating basins. We use them where we anticipate material difficulties on account of tastes and odors in the water.

With aerators of the spray nozzle type, tastes and odors are at least reduced. This has been demonstrated by means of an aerator of spray nozzle type in use at one of the filter plants which furnished water at Berkeley, California. In our own experience we tested out these nozzles with special reference to oily tastes and odors at Whiting, Indiana. These oily tastes and odors were imparted to the water by wastes from the Standard Oil Refinery at Whiting. The tests showed quite clearly that these tastes and odors could be fairly well removed by aeration. The Whiting situation, however, involved a complication. Subsequent to the preliminary tests and prior to the completion of the filter plant, the Mark's Steel Works

TABLE 1

Water spraying nozzles for aeration basins

TABLE 1

Water spraying nozzles for aeration basins

NAME OF FIRM	LABEL	ORIFICE DIAM.	PIPE DIAM.	CAPACITY—(GALLONS PER MINUTE)								
				5 pounds	6 pounds	7 pounds	8 pounds	9 pounds	10 pounds	15 pounds	20 pounds	25 pounds
		inches	*inches*									
Spray Engineering Co., Boston, Mass., "Spraco"	8A	5/16	1	5.4	5.8	6.3	6.7		7.6	9.5	10.8	11.9
	9A	3/8	1¼	7.8	8.6	9.3	10.0		11.2	13.7	15.6	17.5
	10A	½	1½	12.0	13.0	14.0	14.9		16.6	20.3	23.7	26.6
	10B	⅝	1½	21.0	22.8	24.5	26.2		29.8	36.6	42.2	47.2
	11B	¾	2	33.6	36.8	39.8	42.6		47.8	58.4	67.4	75.6
	11B	⅞	2	48.0	52.9	57.6	61.7		68.0	83.3	96.1	107.7
	12B	1 1/16	2½	58.8	64.5	69.5	74.5		83.3	101.7	117.5	131.5
	12B	1 1/16	2½	67.3	73.5	79.5	85.3		95.5	117.3	135.0	151.2
	13A	1 5/16	3	116.0	123.0	129.0	136.0		149.5	182.5		
E. B. Badger & Sons, Boston, Mass.	8	5/16	1	5.0			6.5		7.0	9.0		
	9	3/8	1½	7.5			9.5		10.7	13.0		
	10	½	1½	14.0			17.0		21.0	25.0		
	11	⅝	1½	22.0			28.0		32.0	39.0		
	12	¾	2	33.0			42.0		47.0	57.0		
	13	⅞	2	45.0			58.0		65.0	79.0		
	14	1	2½	60.0			76.0		85.0	105.0		
The Star Brass Works, 3114–22 Carroll Ave., Chicago Ill.	2	¼	¾	2.90	3.14	3.38	3.62	3.86	4.10			
	3	5/16	1	5.87	6.34	6.81	7.28	7.75	8.32			
	4	⅜	1¼	8.5	9.19	9.88	10.57	11.28	11.95			
	5	½	1½	14.26	15.44	16.62	17.80	18.98	20.16			
	6	¾	2	32.0	34.6	37.2	39.8	42.4	45.3			
	7	1	2½	56.8	61.4	66.0	70.6	85.2	80.2			
	8	1¼	3	83.6	92.9	101.3	109.6	117.9	125.5			
Schutte & Koerting Co., Philadelphia, Pa.			2½	77.0	85.0	92.0	98.0	103.0	106.0			
			3	115.0	125.0	133.0	140.0	146.0	151.0			

at East Chicago completed a by-product coke oven plant which produced liquid wastes containing phenol compounds. These wastes entered a sewer discharging into Lake Michigan at a point that permitted them, under certain conditions of wind, to drift over the intake. The characteristic taste of the phenol compounds was intensified by the chlorine treatment, with the result that the water contained tastes and odors that could not be removed by aeration. These tastes and odors are distinguishable from the oily ones caused by the Standard Oil wastes.

A BALANCING RESERVOIR[1]

By Wm. A. Megraw[2]

A so-called balancing reservoir has recently been completed in connection with the Gunpowder River improvements to the water supply of Baltimore. The reservoir was constructed as a means of limiting the pressure on the tunnel conducting water from the Gunpowder River to the city. The accompanying diagrammatic sketch shows the reservoir with respect to the other parts of the water works to which it is related.

A short description is necessary to explain the need for the reservoir.

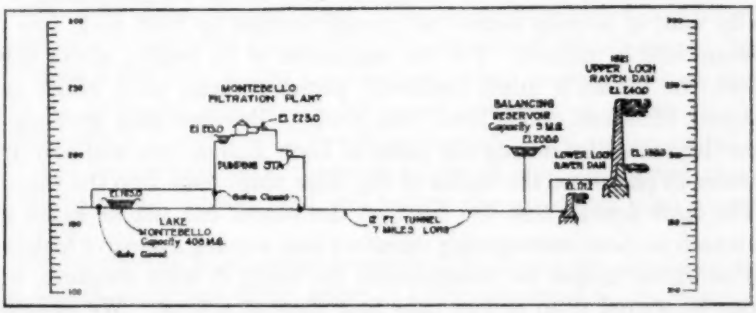


Fig. 1. Diagrammatic Sketch Showing Balancing Reservoir in Relation to Parts of Water Works Affected by Raising Loch Raven Dam

The first Gunpowder works, which were completed in 1888, are composed of a low masonry dam across the river at Loch Raven, now known as the lower dam, Lake Montebello, a tunnel 12 feet in diameter and 7 miles long from Loch Raven to Lake Montebello, and distributing mains from Lake Montebello to the city. The second Gunpowder works, which were completed in 1915, are composed of a low dam, now known as the upper dam, a filter plant, a pumping station to raise water from the tunnel to the filters, a filtered water reservoir and large distributing mains from the filtered

[1] Presented before the Philadelphia Convention, May 19, 1922.

[2] Water Engineer, Baltimore, Md.

water reservoir to the city. Upon completion of the filters, valves on the conduit leading to and from Lake Montebello were closed and the low service zone of the city took the greater pressure, due to the higher water surface in the filtered water reservoir. With this new system of operation, the tunnel was subjected to an additional head of 17 feet, represented by the difference in elevation between the upper and lower dams. The third Gunpowder works were started in 1920 and, at the time of this Convention, are nearing completion.

The upper dam, now being raised from elevation 188 to elevation 240 above mean tide, will increase the storage from 1.5 billion gallons to 23 billion gallons. If the tunnel were strong enough to sustain the additional head, it would be possible to supply the filters by gravity for most of the time and resort to pumping only when the water surface in Loch Raven reservoir dropped considerably below the crest of the dam.

The tunnel is 12 feet in diameter. For about six miles from the city end, it is deep below the ground surface in hard rock free of seams and is unlined. For the remainder of its length, about 6000 feet, the tunnel is much shallower, passes through mica schist and seamy limestone and is lined with brick. Pressure tests were made on the tunnel by closing the gates at Loch Raven dam and allowing water to pass from the basins at the filter plant back into the tunnel. The tests proved that the head on the tunnel can not be much increased without endangering its safety and causing excessive leakage. The tunnel might be strengthened by lining it with concrete, but can be spared from service only four days at a time. We estimate that three years would be required for lining it throughout, during which period of successive watering and unwatering, pressures throughout the low service zone in the city would change with every change of operation. Further, the city has been faced with a water famine with every dry year, so filling the large impounding reservoir as soon as possible takes precedence over all other water works consideration, and the city may not wait for a tunnel lining.

An outlet was provided in the new Loch Raven gate house for an additional tunnel, which should be built when the operating costs of the increasing pumpage equal the carrying charges on a new tunnel.

As the tunnel cannot be operated under much additional pressure, means of relieving the pressure to be imposed by the high dam had to be found. If the entrance of water through the tunnel could

be exactly regulated, the head would not be increased, but the flow through the tunnel must vary from hour to hour with the fluctuating demands of the city and the gate openings at Loch Raven cannot be adjusted to follow immediately the change in demand. If a pump were thrown out of service or the electric plant momentarily failed, throwing all the pumps out of service, pressure would rapidly build up in the tunnel.

If water were passed from the tunnel directly into Lake Montebello, pressure on the tunnel would be relieved but it would be necessary to discard the existing pumping station and install a new station on the shore of the lake to pump from the lake to the filters against a fifty per cent higher head than before.

It was recalled that water stood in an abandoned quarry, located approximately over the tunnel and about 4300 feet from Loch Raven, which was dry before the second Gunpowder works were built, and that the surface of this water rose when storm waters flowed over Loch Raven dam. The quarry occupies a natural depression in the hills, which might be converted into a reservoir by throwing a low dam across the hills and would provide a water surface at elevation 200, which was predetermined as desirable. A water surface at elevation 200 will increase the head on the tunnel 8 feet and its carrying capacity to as much as the impounded river is estimated to furnish, and will reduce the pumping head about one-fifth.

The function of a balancing reservoir is to supply the deficiency to the pumps when too little water is being admitted to the tunnel, and to absorb the excess when too much is being admitted.

The cost of the balancing reservoir was estimated to be about one-tenth that of a new pumping station. Plans were prepared and a contract was awarded to Thomas Mullen of Baltimore on September 10, 1921, for building the reservoir and appurtenances. All work was completed in April, 1922.

The reservoir is irregular in outline. The bottom is a natural clay overlying rock. The dam forming the closure in the hills is of earth taken from the bottom and sides of the reservoir and rolled in 6-inch layers. The inside slope of the dam is one on three and the outside slope one on two. The inside slope is lined with concrete slabs. The old quarry occupies one corner of the reservoir. A vertical shaft through soft rock provides communication between the tunnel and the reservoir. The shaft is 12 feet in diameter and

is lined with reinforced concrete. Six 36-inch diameter flanged openings are arranged radially around the shaft, their inverts at elevation 190, which is the elevation of the reservoir bottom. The dam is at the opposite side from the shaft and as the original ground surface sloped away from the shaft toward the dam, it was necessary to regrade a portion of the bottom, in order that the entire contents of the reservoir may empty through the shaft into the tunnel.

The greatest depth of water is 10 feet, so with small variation in head the entire contents is available. The capacity is about 9,000,000 gallons.

A concrete lined channel 20 feet wide at the bottom, having sloped sides, pierces a hillside beyond the dam to serve as a spillway.

The electric current feeding the pumping station is occasionally interrupted, whereupon the pumps run backwards and a shock is produced by the contact between the water moving forward in the tunnel and the water moving backwards from the filter plant. The contract provided a second shaft 12 feet in diameter over the tunnel about 300 feet from the Montebello Pumping Station, with the top open and at elevation 201, to provide overflow and relief for the shock of surging waters.

Entrance to the tunnel at Loch Raven is controlled by eleven 3 feet 6 inches by 6 feet sluice gates placed at three different elevations.

On April 11, 1922, the relief openings in the New Loch Raven dam were closed, allowing water to rise back of the dam. On May 6, the surface had risen to elevation 201 and gate regulation was then necessary to prevent water in the balancing reservoir wasting over the spillway. Gate regulation must continue until water overtops the Loch Raven dam, after which it will be desirable probably to set the gates, permitting a portion of the excess flow of the river to fall continuously over the spillway at the balancing reservoir, thus saving attendance and wear and tear of the gates. The height of water in the gate chamber back of the gates indicates the height of water in the balancing reservoir and a self-recording gauge gives the gateman all the information he needs. A turbine pit was left in the gate chamber in which an hydro-electric unit may be placed, for mechanically operating the gates and for lighting the dam.

The cost of the reservoir and appurtenances was approximately $60,000.

PLANT CONTROL OF CHLORINATION BY THE EXCESS CHLORINE METHOD, AS EMPLOYED IN NEW YORK CITY'S SUPPLIES[1]

By Frank E. Hale[2]

At the suggestion of the United States Public Health Service and following conferences between that Service, the State Department of Health, the City Department of Health and the Department of Water Supply, Gas and Electricity, the control of chlorination, by maintaining an excess of chlorine at the plants, was adopted and put in operation in July, 1921. The chief inspiration was Wolman's exposition of its effectiveness in Maryland (*Jour. Ind. Eng. Chem.*, vol. 11, March, 1919, No. 3, and *Eng. News-Record*, vol. 86, April 14, 1921, p. 639). While the method is not new, his work has crystallized its importance.

CONTROL BY RESIDUAL CHLORINE ACTUALLY IN THE SUPPLY

Wolman recommends maintaining 0.2 p.p.m. excess after five minutes absorption, basing dosage on bottle experiments starting with 1 p.p.m. available chlorine. He makes, however, quoting from the *News-Record*, also the following recommendation, "In general, the simplest form of chlorination control, and the one which should give complete satisfaction, would consist in maintaining a quantitative residual of chlorine at a definite station near the point of application of the chemical." This principle appeals strongly to the writer, because it gives an actual control of the practical operation. One may know the correct dosage, but due to unavoidable and unforeseen mishaps or conditions, the correct amount of chlorine may not reach the supply. Maintaining an actual excess in the supply assures that the water has actually been properly treated.

[1] Presented before the Philadelphia Convention, May 19, 1922.

[2] Director of Laboratories, Department of Water Supply, Gas and Electricity, New York, N. Y.

MAINTENANCE OF 0.10 RESIDUAL CHLORINE AFTER TEN TO THIRTY MINUTES

In applying the process on this latter principle to a large supply, a five minute interval is generally too short to allow of adequate admixture of chlorine and water, hence we have adopted the maintenance of 0.10 excess after a contact interval of ten to thirty minutes. At five minutes, absorption is progressing rather rapidly but by ten minutes has become largely stabilized. Seventy-five comparisons on Croton water at ten and thirty minute intervals showed an average increase of 0.02 p.p.m. chlorine absorption at the longer interval. Similar results have been obtained at the Long Island plants. Experience so far has also indicated that 0.10 excess covers daily variations in absorption by the main supplies, which are not subject apparently to rapid fluctuation.

RESIDUAL CHLORINE DETERMINED BY INCREASE OF ORTHO-TOLIDIN REACTION

The residual chlorine has been determined by ortho-tolidin by the plant operators and not by the laboratory division. Colorimetric standards are used in 100 cc. Nessler jars of the tall type used for color (height to mark 24 cm.). For some unknown reason most of the supplies give a test with ortho-tolidin before they reach the chlorination plants. This is largely connected with sediment, possibly due to iron or manganese. The reactive power will also accumulate on the inside surface of glass containers. It may be partly due to the fact that portions of the supplies are chlorinated before reaching the final plants. The reaction has ranged from 0.01 to 0.14 p.p.m. on both the Catskill and the Croton supplies. Hence the rule was established to obtain the ortho-tolidin reaction before and after chlorination and to maintain an increase of 0.10 p.p.m.

RELATION OF DOSAGE TO ABSORPTION

Absorption of chlorine is influenced not only by time for a given organic content, but also and largely by initial dose. When a substantial excess is applied such as 1 to 2 p.p.m., absorption is stabilized more quickly and also is greater than when 0.10 excess is maintained. In plant operation considerable latitude must be expected and allowed. The personal element, variation in comparison tubes, etc., may account for minor variations up to probably 0.05 p.p.m.

Many comparisons with varying excess residual chlorine in the actual plant experience indicate that, if a certain dose maintains an increase of 0.10 p.p.m. residual chlorine and that dosage is increased, approximately an average of 50 per cent of the increase of dosage appears as increased absorption and 50 per cent as increased residual chlorine. A few illustrations will suffice:

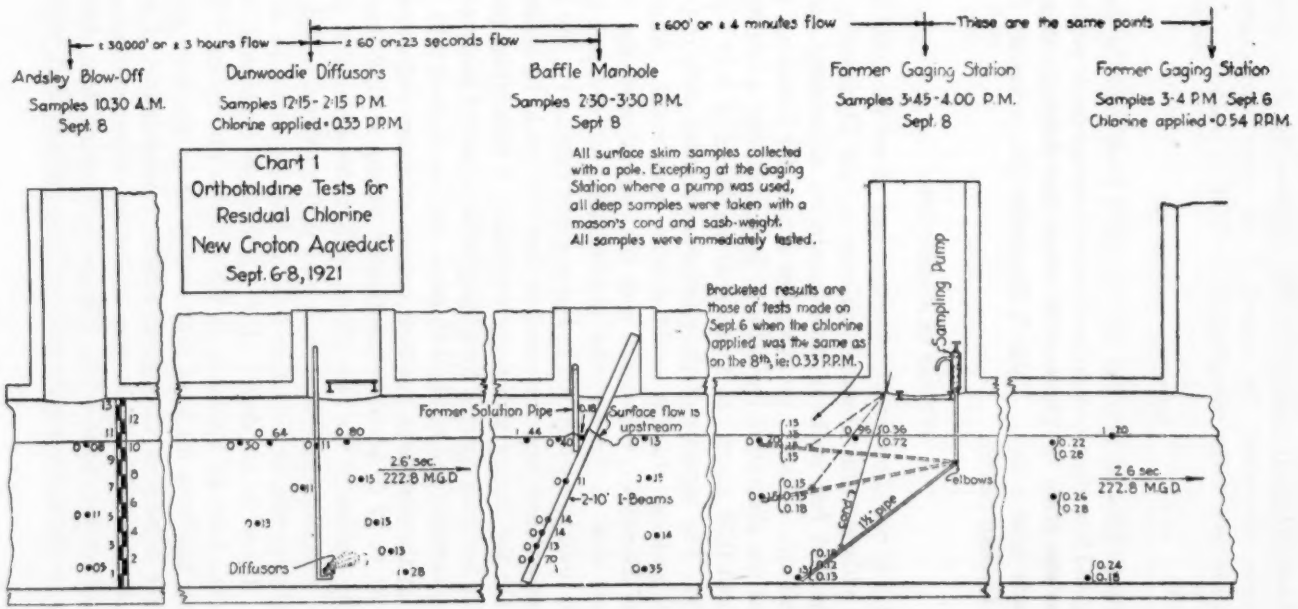
	CHLORINE DOSE	RESIDUAL CHLORINE	ABSORBED CHLORINE
Kensico Plant			
June 6	0.15	0.06	0.09
June 9	0.27	0.12	0.15
Increase	0.12	0.06	0.06 = 50 per cent of increase in dosage
January 17 (experiment)	0.76	0.28	0.48
Week of March 4	0.44	0.10	0.34
Increase	0.32	0.18	0.14 = 40 per cent of increase in dosage
Dunwoodie Plant			
September 24	0.34	0.11	0.23
October 1	0.48	0.17	0.31
Increase	0.14	0.06	0.08 = 57 per cent of increase in dosage
Experiments September 6–8, averages of several tests			
September 6 and 8	0.33	0.07	0.26
September 6	0.54	0.17	0.37
Increase	0.21	0.10	0.11 = 52 per cent of increase in dosage

Of course a change in absorptive power of the water may explain such occurrence, but the fact has been many times observed on the day the dosage was changed and the change is at times too great to be thus explained. Fifty per cent is likewise an average figure, with wide variations occurring. Changes under 0.03 usually do not follow the rule.

IMPORTANCE OF THOROUGH AND REPRESENTATIVE ADMIXTURE OF CHLORINE AND WATER

Of first importance for bacteriological results and for chlorine control is the adequate admixture of chlorine with the water. The method has been applied at Kensico plant on the Catskill supply, at Dunwoodie on the Croton, at Milburn and at Smith's pond on the Long Island supply. At Kensico, thorough and rapid admixture is obtained by the agitation of the water in the gate house and passage through a venturi section (the latter being particularly efficient as shown by laboratory experiments with permanganate and a miniature venturi). Samples taken at various points at Kensico have proven this rapid admixture in practice. At Milburn, admixture is obtained by passage through a pump well and the pumps, at Smith's pond by baffles, 5-feet high. Great trouble was experienced at Dunwoodie. Samples at first were very irregular. Then two "I" beams were inserted about 60-feet below the chlorine diffusors, and the regular sampling point for chlorine regulation was established at 600 feet. The accompanying chart 1 shows the various results obtained at different points after introduction of the baffles. (I am indebted to Theodore DeLong Coffin, Assistant Engineer, Croton watershed, for these experiments and for the chart.) It will be noted that a stratum of highly chlorinated water forms near the bottom at the diffusors and gradually decreases to average at 600 feet. A surface film of high chlorine also appears even at some distance down stream, probably due to downward absorption of bubbles of chlorine gas which have coalesced and ascended rapidly through the water. While there is some variation, samples at 600 feet, due to agitation by the baffles, are sufficiently representative, except directly on the surface and at the bottom. The average orthotolidin readings at the 600-foot point, without correction for the reaction above the point of introduction of chlorine, were as follows:

	DOSAGE	
	0.33 p.p.m.	0.54 p.p.m.
Top	0.16	0.25
Middle	0.16	0.27
Bottom	0.14	0.19


± 30,000' or ± 3 hours flow
± 60' or 23 seconds flow
± 600' or ± 4 minutes flow
These are the same points
Ardsley Blow-Off
Samples 10.30 A.M. Sept. 8
Dunwoodie Diffusors
Samples 12-15 - 2-15 P.M.
Chlorine applied - 0.33 P.P.M.
Baffle Manhole
Samples 2.30 - 3.30 P.M. Sept 8
Former Gaging Station
Samples 3-45 - 4.00 P.M. Sept. 8
Former Gaging Station
Samples 3-4 P.M. Sept. 6
Chlorine applied - 0.54 P.P.M.
Chart 1
Orthotolidine Tests for Residual Chlorine
New Croton Aqueduct
Sept. 6-8, 1921
All surface skim samples collected with a pole. Excepting at the Gaging Station where a pump was used, all deep samples were taken with a mason's cord and sash-weight. All samples were immediately tested.
Bracketed results are those of tests made on Sept 6 when the chlorine applied was the same as on the 8th, ie: 0.33 P.P.M.
Former Solution Pipe
Surface flow is upstream
2-10' I-Beams
Diffusors
2.6' sec.
222.8 M.G.D.
Sampling Pump
Elbows
1½" pipe
cord
2.6 sec.
272.8 M.G.D.

The bacteriological samples for the Dunwoodie plant have been taken three miles down the aqueduct, no convenient nearer point being available with the exception of the 600-foot point.

ROUTINE PROCEDURE

Determinations for residual chlorine have been made in the early morning and late afternoon and a change of dosage made accordingly, with the exception of Dunwoodie where the determinations have been made once a day. Table 1 illustrates the procedure for one week at the four plants.

STUDIES OF ABSORPTION

Chart 2 is based on weekly averages and shows the total dosage, residual chlorine and absorbed chlorine at the Dunwoodie plant. After the first few weeks of experimentation adjustment has been fairly uniform. Chart 3 gives similar results for Kensico. But at this plant the absorption has steadily increased from a low figure in July, about 0.10 p.p.m., to a probable maximum of 0.35 p.p.m. in February. The capacity of the plant was exceeded early in October and 0.10 residual chlorine could not be maintained. About the middle of December, coincident with the beginning of the trouble from taste due to Synura, the residual chlorine dropped rapidly from 0.07 until it reached 0.02 in January and February. By March the equipment had been increased so that 0.10 could be maintained again. On the theory previously expressed, a theoretical probable absorption has been charted by adding to the apparent absorption the difference between the residual chlorine and the desired 0.10 p.p.m. The dip in the dosage in January was an arbitrary reduction from January 11 to 17 to avoid destruction of Synura at that time. An interesting feature of the two plants is that the amount of absorption has reversed itself—in July it was 0.10 at Kensico and about 0.40 at Dunwoodie, in February 0.35 at Kensico and 0.13 at Dunwoodie. There is no doubt that microscopic organisms, organic matter, etc., have an influence on the chlorine absorption. Extensive study has been made of both waters as to the total count of microscopic organisms, amorphous matter, predominance of various species, albuminoid ammonia, sum of free and albuminoid ammonia, nitrite and nitrate, total solids, alkalinity, chlorine, iron, turbidity and color, as shown by weekly analyses, also amount of B. coli in the

TABLE 1

DATE 1921, OCTOBER	RESIDUAL CHLORINE			CHLORINE APPLIED	CHLORINE ABSORBED	BACTERIA PER CUBIC CENTIMETER		B. COLI PER 10 cc.	
	Before	After	Increase			Raw	Chlorinated	Raw	Chlorinated
(Kensico Plant—Catskill Supply—Approximate 425 m.g.d.)									
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*				
22 p.m.	0.06*	0.14	0.08	0.30	0.22	5	0	5	0
24 a.m.	0.06	0.15	0.09	0.30	0.21	10	1	1	0
24 p.m.	0.06	0.14	0.08	0.30	0.22				
25 a.m.	0.06	0.14	0.08	0.30	0.22	3	1	1	0
25 p.m.	0.07	0.14	0.07	0.30	0.23				
26 a.m.	0.07	0.13	0.06	0.30	0.24	5	2	1	0
26 p.m.				0.30					
27 a.m.	0.06	0.13	0.07	0.29	0.22	4	1	1	0
27 p.m.	0.05	0.13	0.08	0.31	0.23				
28 a.m.	0.06	0.14	0.08	0.28	0.20	2	0	1	0
28 p.m.	0.07	0.14	0.07	0.31	0.24				
29 a.m.	0.06	0.13	0.07	0.31	0.24	7	0	1	0
(Dunwoodie—Croton Supply—Approximate 250 m.g.d.)									
23	0.12	0.24	0.12	0.48	0.36	41	4	1	0
24	0.12	0.22	0.10	0.48	0.38	87	5	0	0
25	0.10	0.20	0.10	0.48	0.38	19	6	1	0
26	0.10	0.20	0.10	0.48	0.38	28	1	0	0
27	0.08	0.20	0.12	0.46	0.34	180	6	1	0
28	0.10	0.20	0.10	0.46	0.36	23	22	5	0
29	0.08	0.18	0.10	0.46	0.36	26	7	5	0
(Smith's Pond—Long Island System—Approximate 2 m.g.d.)									
24 a.m.	0.01	0.13	0.12	0.54	0.42	11	1	1	0
24 p.m.	0.01	0.12	0.11	0.54	0.43				
25 a.m.	0.01	0.12	0.11	0.54	0.43				
25 p.m.	0.01	0.10	0.09	0.54	0.45				
26 a.m.	0.01	0.12	0.11	0.54	0.43	11	2	0	0
26 p.m.	0.01	0.12	0.11	0.54	0.43				

TABLE 1—*Continued*

DATE 1921, OCTOBER		RESIDUAL CHLORINE			CHLORINE APPLIED	CHLORINE ABSORBED	BACTERIA PER CUBIC CENTIMETER		B. COLI PER 10 cc.	
		Before	After	Increase			Raw	Chlorinated	Raw	Chlorinated
(Smith's Pond—Long Island System—Approximate 2 m.g.d.)—Continued										
		p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*				
27	a.m.	0.01	0.11	0.10	0.54	0.44				
	p.m.	0.01	0.10	0.09	0.54	0.45				
28	a.m.	0.01	0.12	0.11	0.54	0.43	310	4	1	0
	p.m.	0.01	0.10	0.09	0.54	0.45				
29	a.m.	0.01	0.10	0.09	0.54	0.45				
	p.m.	0.01	0.11	0.10	0.54	0.44				
30	a.m.	0.01	0.11	0.10	0.54	0.44				
	p.m.	0.01	0.10	0.09	0.54	0.45				
(Milburn—Long Island System—Approximate 25 m.g.d.)										
24	a.m.	0.01	0.10	0.09	0.33	0.24	8	1	10	0
	p.m.	0.01	0.11	0.10	0.33	0.23				
25	a.m.	0.01	0.10	0.09	0.31	0.22				
	p.m.	0.01	0.12	0.11	0.31	0.20				
26	a.m.	0.00	0.13	0.13	0.30	0.17	0	1	0	0
	p.m.	0.00	0.11	0.11	0.30	0.19				
27	a.m.	0.00	0.10	0.10	0.30	0.20				
	p.m.	0.00	0.11	0.11	0.30	0.19				
28	a.m.	0.00	0.12	0.12	0.30	0.18	2	2	0	0
	p.m.	0.00	0.11	0.11	0.30	0.19				
29	a.m.	0.00	0.10	0.10	0.30	0.20				
	p.m.	0.00	0.12	0.12	0.30	0.18				
30	a.m.	0.00	0.10	0.10	0.30	0.20				
	p.m.	0.00	0.12	0.12	0.30	0.18				

raw water, and yet no definite correlation appears. The absorption is probably a resultant of many factors and is only determined by the chlorine itself. Chart 4 compares the absorption values at the four plants and offers a fruitful study of the variations in the demand of different waters for chlorine.

Chart 2- Chlorination of Croton Water at Dunwoodie

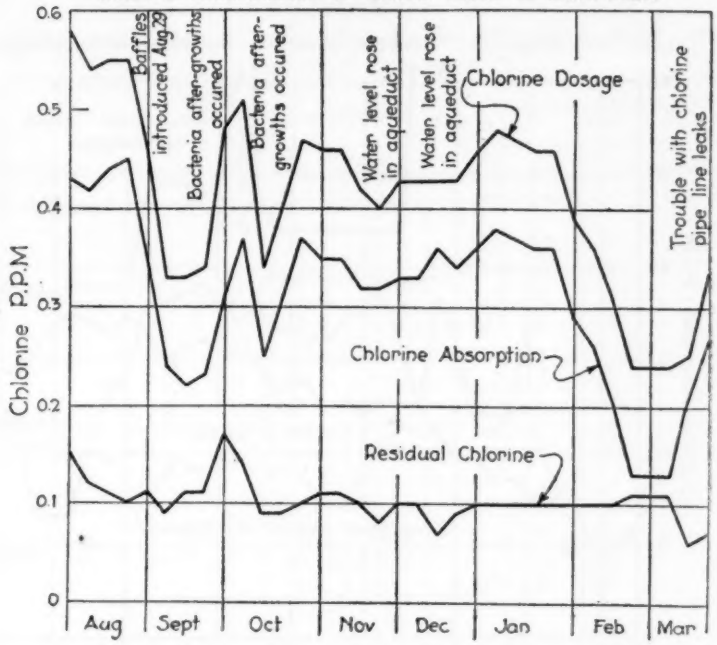
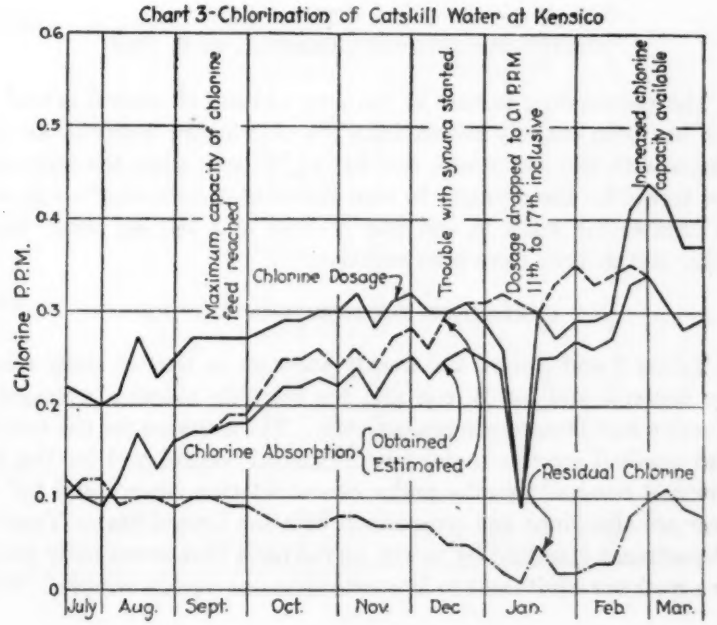
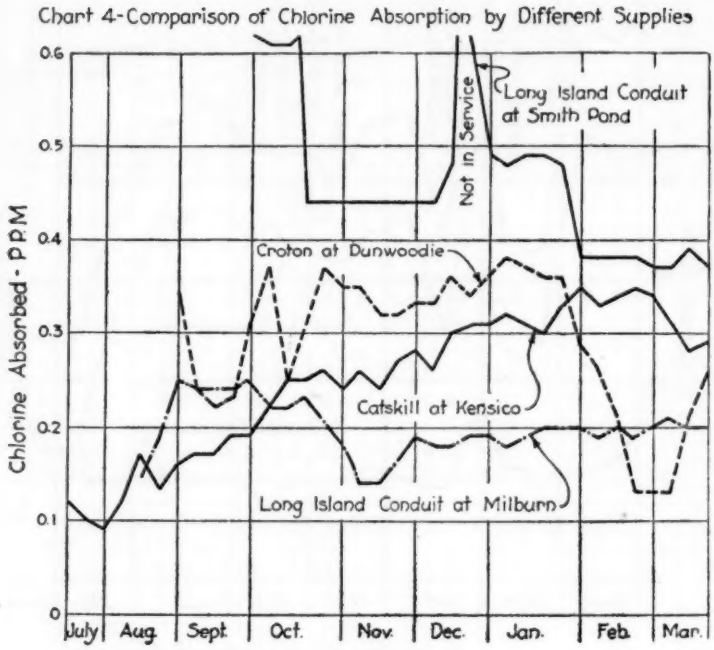


Chart 3- Chlorination of Catskill Water at Kensico





CONTINUOUS COMPLETE REMOVAL OF B. COLI

The outstanding feature of the new method of control is that B. coli has been entirely absent from the chlorinated water in all four plants with two exceptions, one day at Milburn when the water was too turbid for the operator to read the ortho-tolidin results and once at Dunwoodie when B. coli was positive in a 100 cc. test. Many other 100 cc. tests have been negative.

COMPARISON WITH PREVIOUS RESULTS

Tables 2 and 3 show the weekly averages in 1921 of daily results for bacteria and for B. coli and the monthly chlorine averages at Kensico and Dunwoodie respectively. The averages for the first six and one-half months under bacteriological control and for the last five and one-half months under excess chlorine control and for the year are also given and comparison with the United States Treasury Department standard by weeks, on the basis that seven daily results in a week are equivalent to five tests upon one weekly sample. While

TABLE 2

Bacterial results, Catskill water, 1921, Kensico chlorination plant (weekly averages of daily analyses)

1921, MONTH	B. COLI PER 10 CC.		DOSAGE CHLORINE	BACTERIA PER CUBIC CENTIMETER (37°C.)	
	Raw	Chlorinated		Raw	Chlorinated
			p.p.m.		
January	0	0		10	3
	0	0		3	3
	0.33	0		6	3
	0	0	0.06	4	3
February	0	0		3	2
	0	0		3	2
	0	0		3	2
	0	0	0.05	3	3
March	0	0		4	1
	0.17	0		4	2
	0.33	0		4	2
	0	0	0.04	4	2
April	0	0		5	5
	0.17	0		5	4
	0.33	0		5	3
	0.17	0.17		3	2
	0.17	0	0.04	20	4
May	0.33	0		5	3
	0.33	0		6	3
	0.17	0		4	2
	0.17	0	0.13	6	3
June	0	0		9	2
	0	0		12	6
	0	0		12	4
	0.17	0	0.15	9	3
July	0.17	0		9	4
	0.17	0		57	33
	0	0	0.15	8	3
	.....	.....	.....	.....	... Plant control started
	0.50	0		5	1
	0.17	0	0.22	29	2

TABLE 2—*Continued*

1921, MONTH	B. COLI PER 10 CC.		DOSAGE CHLORINE	BACTERIA PER CUBIC CENTIMETER (37°C.)	
	Raw	Chlorinated		Raw	Chlorinated
			p.p.m.		
August	0.67	0		29	5
	0.33	0		20	2
	0.33	0		8	2
	0.33	0	0.23	8	2
September	0.83	0		18	2
	3.40	0		12	5
	0.33	0		19	8
	0.40	0	0.26	25	0
October	2.18	0		32	2
	0.50	0		9	1
	1.00	0		6	1
	1.20	0		7	1
	1.00	0	0.29	5	1
November	0.50	0		4	1
	0.25	0		7	2
	0.33	0		3	1
	0.20	0	0.31	11	1
December	0	0		5	1
	0.17	0		3	2
	0.17	0		4	2
	0	0		3	2
	0	0	0.31	3	2
Average first 28 weeks	0.11	0.006	0.08	8	4
Average second 24 weeks	0.62	0	0.27	11	2
Average year	0.35	0.003	0.17	10	3
U. S. Standard		(0.2)			
Weeks O.K. first period	23/28	28/28			
Weeks O.K. second period	7/24	24/24			
Weeks O.K. year period	30/52	52/52			

TABLE 3

Bacterial results, Croton water, 1921, Dunwoodie chlorination plant (weekly averages of daily analyses)

1921, MONTH	B. COLI PER 10 CC.		DOSAGE CHLORINE	BACTERIA PER CUBIC CENTIMETER (37°C.)	
	Raw	Chlorinated		Raw	Chlorinated
			p.p.m.		
January	0	0		432	19
	0.14	0.14		23	42
	15.7	1.9		49	35
	2.4	0.14	0.13	34	44
February	0	0		11	14
	0	0		13	11
	0	0		47	16
	0	0	0.15	14	13
March	0	0		15	15
	0	0		19	14
	0	0		19	12
	0.14	0	0.11	27	18
April	0	0		13	17
	0	0		18	16
	0.14	0		31	22
	0	0		12	19
	0.29	0.14	0.09	11	12
May	0.29	0.14		52	11
	0	0		26	17
	0	0		13	23
	0.14	0	0.17	24	7
June	0	0.14		105	24
	0	0		13	11
	0	0		49	14
	0	0	0.20	24	10
July	0.29	0		23	12
	0.14	0.14		80	28
	0.29	0	0.20	156	12
	.....	.....	.....	.....	Plant control started
	1.89	0		57	35
	0.29	0	0.55	41	6

TABLE 3—*Continued*

1921, MONTH	B. COLI PER 10 CC.		DOSAGE CHLORINE	BACTERIA PER CUBIC CENTIMETER (37°C.)		
	Raw	Chlorinated		Raw	Chlorinated	
			p.p.m.			
August	3.14	0		107	32	
	1.86	0		165	14	
	0.57	0		201	58	
	0.29	0	0.55	331	31	*Baffles August 29*
September	0.14	0		528	57	
	0.14	0		293	37	
	0.14	0		173	524*	
	0.14	0	0.36	527	240*	
October	0.14	0		409	15	
	0.43	0		153	15	
	0.57	0		106	366*	
	5.00	0		66	7	
	1.86	0	0.42	58	7	
November	0.29	0		98	9	
	0	0		52	6	
	0	0		26	5	
	0.14	0	0.43	535	6	
December	0.14	0		11	3	
	0.14	0		9	3	
	0.06	0		17	6	
	0.01	0		11	6	
	0.02	0	0.44	27	6	
Average first 28 weeks	0.71	0.10	0.15	48	18	
Average second 24 weeks	0.73	0	0.45	167	62	
Average year	0.72	0.05	0.29	103	32	
U. S. Standard		(0.2)				
Weeks O.K. first period	22/28	27/28				
Weeks O.K. second period	13/24	24/24				
Weeks O.K. year	35/52	51/52				

* Aftergrowths.

throughout the year, under both methods, there was only one week when the chlorinated water at the Dunwoodie plant failed to meet the standard and at the Kensico plant only a single day's positive

test was obtained in the entire year, yet it has never occurred before that the fall of the year has passed without a single test for B. coli at any of the plants. In September and October during three weeks, when dosage was as low as 0.33 p.p.m. at Dunwoodie and residual chlorine was slightly below 0.10, bacterial aftergrowths apparently occurred three miles below the plant. Increase of dosage to 0.40 prevented this. The average chlorination results for several years for the Croton and Catskill supplies are given in table 4.

TABLE 4

YEAR	CHLORINE APPLIED		RAW WATER		TREATED WATER		REMOVAL	
	Theory	Analyzed*	Bacteria per cubic centimeter (37°C.)	B. coli per 10 cc.	Bacteria per cubic centimeter (37°C.)	B. coli per 10 cc.	Bacteria	B. coli
Dunwoodie chlorination plant								
	p.p.m.	*p.p.m.*					*per cent*	*per cent*
1917	0.29		24	11.41	13	0.54	46	95
1918	0.32		67	17.04	17	0.43	75	98
1919†	0.20	0.15	82	1.26	16	0.09	80	93
1920	0.16	0.15	125	3.56	31	0.24	75	94
1921	0.29	0.28	103	0.70	32	0.05	69	93
Kensico chlorination plant								
1917	0.23		68	6.15	6	0.62	98	90
1918	0.20		25	0.35	6	0.04	76	90
1919†	0.14	0.14	57	1.49	18	0.09	68	94
1920	0.08	0.11	14	0.52	5	0.10	63	80
1921	0.17	0.16	10	0.37	3	0.003	70	99

* Increase in fixed chlorine, determined on 500 cc., equal analyzed chlorine. Theory determined by weight of chlorine and flow of water.

† Brilliant green bile used since March, 1919.

COST OF INCREASED DOSAGE

While the increased cost of chemical as compared with 1920 will probably average $30,000 a year due to adoption of the new method of control, it will be money well spent to keep the supply absolutely free from B. coli. (These figures are based on a probable average dosage of 0.4 p.p.m. for Dunwoodie and 0.3 p.p.m. for Kensico, against 0.15 and 0.08 for 1920 respectively, an average increase of 0.23. This represents 235 tons of additional chlorine yearly, on 675 m.g.d., which at 6½ cents equal approximately $30,000.)

RELATION TO TYPHOID FEVER

Study of the typhoid statistics for the year would indicate no effect, though results were obtained sufficiently early to have cut out the fall rise almost completely, if that were due to water supply. From the middle of July there was not a test for B. coli in any of the chlorinated water. Cases of typhoid reported should have shown the effect one month later. Chart 5 shows the absence of any effect. Likewise the death-rates for three years from typhoid in New York City, based upon the 1920 census have been 2.2, 2.4 and 2.2 for 1919, 1920 and 1921 respectively.

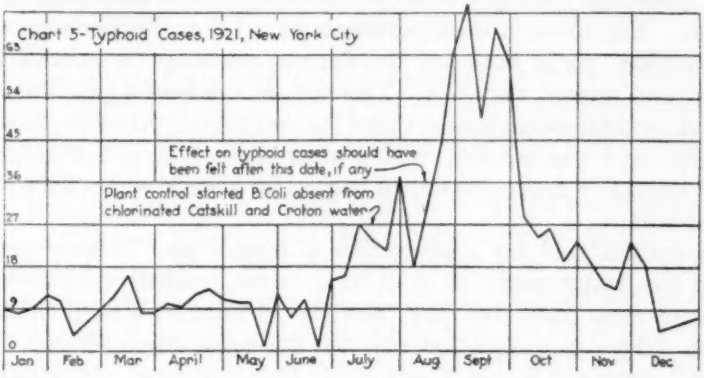
While there was no effect upon the fall rise of typhoid fever, nevertheless, during the last six months from October through March, the reported cases have been only about one-half of the number reported during the corresponding period a year ago. The following table contains the data by months:

Typhoid fever cases reported

MONTHS	1920-21	1921-22	REDUCTION
			per cent
July	89	123	
August	196	154	
September	184	252	
Third quarter	469	529	
October	206	121	41
November	96	69	28
December	88	41	53
Fourth quarter	390	231	41
January	38	17	55
February	29	10	66
March	43	20	53
First quarter	110	47	57

It seems questionable whether this reduction is due to increased chlorination inasmuch as the Catskill water, which is two-thirds of the supply, was practically free from B. coli as it left the chlorination plant *throughout the year*, there being only one day with a positive test. In both of the above periods this water did not reach the dis-

tribution system free from B. coli due to contamination by seagulls at Hillview reservoir. The Croton chlorinated water was also in excellent condition, with the exception of one week in January last year and as it actually reached the distribution system contained only 0.04 B. coli per 10 cc., average for the year. It must also be taken into account that the Board of Health have excluded from the market oysters from the Jamaica Bay district. Of the cases reported last year 40 per cent were traced by the Board of Health to their source. If the improvement above is due to water supply it would mean the cutting out of all the untraced cases.



TASTE AND ODOR

The increased dosage necessitates greater watchfulness against taste and odor, since chlorine has an effect upon many of the microscopic organisms, probably killing the organism and setting free the essential oil. There is no indication of change of character or intensification of the taste or odor.

Our first experience was in February and March, 1919, when 700 units of Tabellaria under influence of 0.15 p.p.m. chlorine produced wide-spread, through not numerous, complaints of fishy taste in Manhattan and Brooklyn.

The recent experience with Synura is common knowledge. At no time did more than about 100 units (not colonies) reach the chlorination plant and taste was produced with 50 or less units. The dosage of chlorine at the time was approximately 0.3 p.p.m. Reduction of the dose to 0.1 reduced the taste, when live organisms were reaching the chlorination plant, but after the organisms were killed by

copper sulphate the taste was not increased by increase of chlorine from 0.1 back to 0.3 p.p.m., but if anything was slightly lessened. This led to experimentation with a still higher dose of chlorine. The details have been published in *Engineering News-Record* of February 16, 1922. It must be understood that these were not laboratory experiments, but large scale plant experiments with the actual supply, though with adequate control so that the public should not suffer if failure resulted. It was found that 0.6 to 0.75 p.p.m. chlorine destroyed the cucumber taste and that the excess chlorine, 0.28 p.p.m. at the time, had disappeared, so that taste of chlorine was not noticeable after a number of hours, a probable maximum of 12 hours. Repetition of the experiment proved that this same amount of chlorine would both kill the Synura, probably 50 units at the time, and destroy the taste. This was on the Bronx pipe line, 12 m.g.d., and the water wasted to the Harlem River. After the success of treatment was assured, treated water was served to the distribution system on a small scale, 10 m.g.d., for a week without a single complaint.

A fruitful field for investigation is opened up. It may prove that the maintenance of a definite excess residual chlorine will prevent such taste and odor, possibly 30 minutes absorption and 0.1 to 0.3 p.p.m. residual chlorine, but the excess should be such that it will disappear within a reasonable length of time. It is also a possibility that excess chlorine might displace copper sulphate in control of certain troublesome microscopic organisms.

WATER RATES[1]

By J. O. Craig[2]

In the management of a water works plant the question of rates should be, and usually is, one of vital concern. Where the water plant is owned by the city or town often this question is not given the consideration it should have, and especially is this true of smaller towns.

In establishing rates, the usual procedure is to write to the neighboring towns and cities for a copy of their rates and to assume that either some particular rate or an average schedule will fit the conditions.

I believe I am safe in stating that, if we superintendents are fair to ourselves, we will all admit that our rates are not just what they ought to be; but if we were to advocate what we know to be right we would soon lose our jobs and conditions would remain the same. In other words, in almost all cases our rates are too low and as long as the majority of the towns in our section have that kind of rate it is a hard matter to remedy the state of affairs.

We, like the manufacturer, have a plant owned by the people of the community as stockholders and we turn out a product for sale that should bring in enough revenue to show a profit on the investment. If the manufacturer does not show a profit his business is soon headed toward bankruptcy and the same argument should apply with equal force to a municipal water plant.

But where we differ from the manufacturer is in the fact that he may expand if he so wishes and his management permits, while the water plant has to expand whether the revenue permits or not. When the community outgrows the manufacturer who fails to make sufficient profit to grow with it, they may purchase their excess somewhere else and he still makes a good living on his investment. However the only source from which the citizens may

[1] Presented before the North Carolina Section meeting, November 14, 1922.

[2] Superintendent, Water Works, Salisbury, N. C.

secure their water is their one water plant and what usually happens is that the plant struggles along as best it may until it becomes absolutely necessary to make some provision for the immediate future. There is no surplus on hand to take care of this emergency so bonds are sold and the people are deluded into the opinion that the town will be well taken care of for the next twenty years of more.

The bonds usually run for twenty years at about five per cent so the people get one hundred dollars worth of work done at a cost of two hundred dollars. In addition to this, when the bonds fall due, some arrangements have to be made to redeem them and this is often done by issuing new refunding bonds making a still further cost.

In building and equipping a new plant bonds may be necessary, but in enlarging and extending an old plant, if we as managers allow the finances to get into such shape that we have to spend two dollars to do the work of one, then we have to admit that we are not men enough to stand up and face the music. Perhaps we cannot help ourselves, but I doubt if any of us have made a serious effort. If we cannot get away from bonds entirely we can at least cut down as much of the additional expense as is practicable.

In order to do this it will be necessary for us to make a summary of the situation and to estimate as closely as possible what extensions will have to be made within the next ten years and then to bring our revenues up to meet the requirements. Most assuredly the rates will be higher, because we are working on the wrong basis now, but in the long run the people will pay less and have more, the only difference being that they will see what they are paying instead of having part of it hid in the taxes.

We are all under the impression that the municipal water plant is owned by the people; but the people only hold title to the property and are the common stockholders, while the preferred stockholders are the outside interests who collect their 4 or 5 per cent as the case may be before any other profit may be distributed in the shape of improvements.

In the case of Salisbury we pay annually $12,800 interest on bonds, to the amount of approximately $250,000 or about half the present plant value. This interest charge is about 15 per cent of our total cash receipts, not including a book charge against the property owners of the city for fire protection. Our rates take care of this item as well as an amount sufficient for ordinary extension, but

sometime within ten or twelve years we will be called upon to make extraordinary extensions to the amount of about $100,000 and are not laying up anything at all on that account. The interest which we are now paying would amount in ten years to $128,000 and our present rates would take care of it. If we might wipe our slate clean our rates would not need to be high. A 10 per cent raise in our rates would nearly cover our situation, provided of course the water department has complete control over its finances.

And this is the one thing that keeps our rates from being what they should be. Almost every city and town has a slightly different method of handling their water department. The ideal way would be to have a board of water commissioners who had complete power to buy and sell, borrow or loan, and even to issue first mortgage bonds where necessary. But this is not always possible and where the town handles the bonds it is a hard matter to keep the record straight, especially if there is an offset charge against the city for fire protection. As an instance we will suppose our interest charges on bonds are $5000, which the city treasurer pays; then there is an offset charge against the city of $8000 for fire protection and the public use of water. This would give the water department a credit of $3000 according to their books, but if they happen to need this amount next year to make some extensions they will not be able to find it.

This is an instance where the water department is better managed than the rest of the city, but this is not always the case. For, on the other hand, the interest charge may be considerably in excess of that due the water department and the department may not have sufficient funds to turn over the difference.

In other instances the city treasurer pays all bills and the water department merely attends to operation. In such a case, it is almost impossible to keep the records straight or to determine whether the rates are fair and just or not.

It seems to me that the only way to arrive at a basis of rate making is for the water department to have a complete record of its assets and liabilities, receipts and disbursements and to insist that their finances be kept in a separate account. In this way they will know with some degree of accuracy what their obligation will be and may arrive at a rate that will take care of it. But this rate should enable them always to have a surplus, except at times of heavy expense for extension and enlargement.

The residents of Salisbury believe they have a good water system with good water service and reasonable rates. They think they have good management and are getting along finely, so it seems to be a pity to wake them up, but I am willing to start the argument even if some one else has to finish it, provided one or two others will join in the fight.

I think I will be excused if I name a few towns who should welcome an agitation for higher rates at this time. Charlotte is to make extensive improvements at considerable cost, and even with her ample resources and large number of consumers, it is doubtful if her natural growth in receipts will equal this extra expense. The same thing applies to Greensboro. I do not know the exact status of the Raleigh situation, but they will have to spend a considerable sum before long. Lexington is installing a new plant of such proportions that their old rate will be entirely out of line, unless they may secure some large water consumers at a profitable rate. Leaksville is installing water and sewerage for the first time on such an extensive scale that rates in vogue in other places will not meet their requirements and if we are called upon for copies of our rates to assist them we should stress that fact. The same argument would apply to at least three-fourths of the towns in North Carolina.

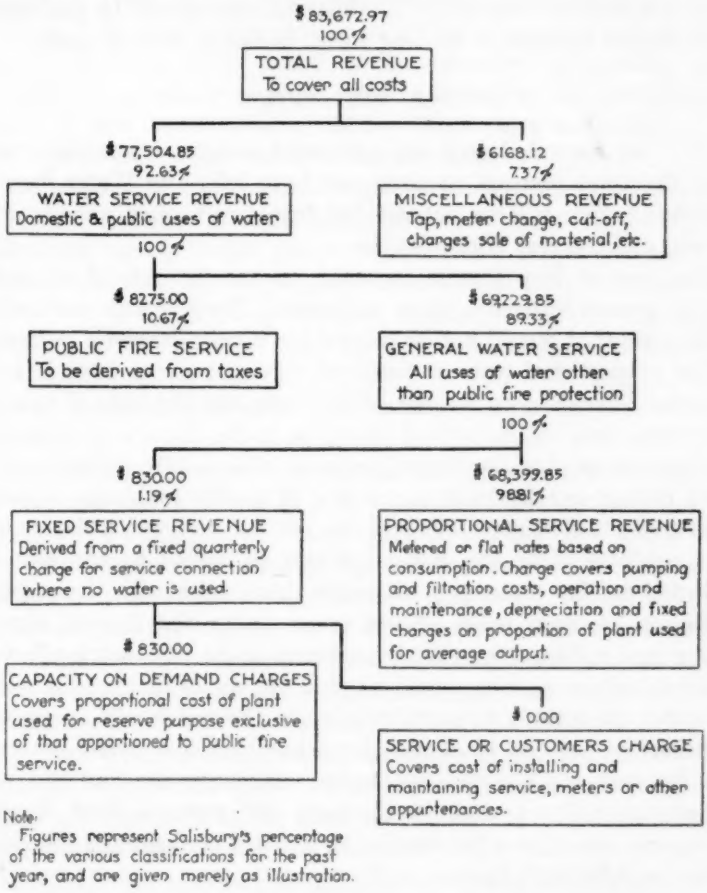
When we start to establish rates we may as well take these costs into consideration now instead of deferring them to the future. A certain interest charge has to be met and an amount must be set aside for a sinking fund or surplus as the case may be. Instead of making some arbitrary rate and allowing the town to take care of the remainder through taxes, we should determine what per cent should be chargeable against the property owners and what per cent for the actual sale of water. No two towns have exactly the same conditions, so no set rule may be given, but the general rule is that the larger the town the smaller the proportion chargeable through taxes for fire protection and public water service.

At the Buffalo Convention of the American Water Works Association in 1919 the Committee Report on Private Fire Protection Service covered the field thoroughly and I am indebted to them for the method of grouping and proportioning the percentage of revenue.

I am using their diagram practically as it appears in Vol. 6, No. 4, of the Proceedings of the American Water Works Association, November, 1916, except that I have condensed the wording of some of the group definitions.

MISCELLANEOUS REVENUE

In analyzing this diagram one of the first sub-divisions is Miscellaneous Revenue, which includes tap fees, turn off and turn on charges, any charge connected with installing or repairing meters, rent of property, interest on deposits, sale of material, or any other revenue outside of Water Service Revenue.


$83,672.97
100%
TOTAL REVENUE
To cover all costs
$77,504.85
92.63%
WATER SERVICE REVENUE
Domestic & public uses of water
$6168.12
7.37%
MISCELLANEOUS REVENUE
Tap, meter change, cut-off, charges sale of material, etc.
100%
$8275.00
10.67%
PUBLIC FIRE SERVICE
To be derived from taxes
$69229.85
89.33%
GENERAL WATER SERVICE
All uses of water other than public fire protection
100%
$830.00
1.19%
FIXED SERVICE REVENUE
Derived from a fixed quarterly charge for service connection where no water is used.
$68,399.85
98.81%
PROPORTIONAL SERVICE REVENUE
Metered or flat rates based on consumption. Charge covers pumping and filtration costs, operation and maintenance, depreciation and fixed charges on proportion of plant used for average output.
$830.00
CAPACITY ON DEMAND CHARGES
Covers proportional cost of plant used for reserve purpose exclusive of that apportioned to public fire service.
$0.00
SERVICE OR CUSTOMERS CHARGE
Covers cost of installing and maintaining service, meters or other appurtenances.
Note:
Figures represent Salisbury's percentage of the various classifications for the past year, and are given merely as illustration.

There is no rule for proportioning this revenue, except that it should cover the cost of the work approximately. Some towns do not make a charge for tapping the main and some tap the main but do not run to the property, but the opinion of the majority is that the water department should be responsible for all pipe within the

city streets and that they should make a fixed charge proportionate to the average cost of making the connection for that particular size. It is manifestly unfair to make the same charge for a 2-inch as for a $\frac{5}{8}$-inch house connection, for even though the large connection may bring in more revenue they get the full advantage of this through the lower rate for water.

In my opinion the tap fee should be the same for all taps of the same size, and the charge for the different sizes should be graduated according to the cost of making them, including cost of meter.

PUBLIC FIRE SERVICE

After we have deducted the estimated revenue from this source from the total revenue required, we have left—the Water Service Revenue. This will be sub-divided into two groups namely Fire Service and General Water Service.

The cost of Fire Service is based on the investment of larger mains, greater capacity, more equipment, fire hydrants and other incidentals that would not be needed for purely domestic purposes.

The proportional revenue based on this cost varies from 5 to 50 per cent depending on the size of the town and the type of system. The figure that will be arrived at will be in the shape of a lump sum or fixed charge, but for future purposes it is usually divided into a fixed charge per hydrant per year. If public buildings, schools, flush tanks and other public supplies are not metered, a flat charge in accordance with this service should be added to the amount collected for fire protection, although this service with the possible exception of flush tanks should come under the general service charge and collected from the department of the city that is affected.

All the above service should be paid for out of taxes, as it would be unfair for tenants to have included in the water rate an amount sufficient to pay fire protection for a landlord who might not even pay for any water service whatever. Salisbury has had this case tested out in Court, whereby the town sold water to East Spencer at a meter rate plus a flat charge per hydrant per year and the Court found in Salisbury's favor.

PROPORTIONAL SERVICE REVENUE

While the other sub-division, namely General Water Service, is sub-divided into several groups we shall confine our discussion to the

first two main groups—the Fixed Service Charge and the Proportional Service Charge.

The present tendency, especially in the larger cities, is to have a fixed service charge per quarter or month proportional to the size of connection, which charge is collected whether water is used or not. In addition to this charge, an additional charge for the entire amount of water used according to the meter rate is made. With this method in vogue it is of course necessary to meter all services.

At the Philadelphia Convention in 1922 the Committee on Quantities for Slides in Meter Schedules recommended the standard form of meter rate schedule which had been adopted by the New England Water Works Association in 1916. These rates are explained in detail in volume 9, number 4 of this JOURNAL.

The recommendation of the Committee is for three steps or slides—the first, called the Domestic Rate, includes all water up to 300,000 gallons per year or 75,000 gallons per quarter. The second or intermediate rate applies to quantities in excess of 300,000 gallons per annum up to 3,000,000 gallons per annum. The Third or Manufacturing and Wholesale Rate applies to quantities in excess of 3,000,000 gallons per year.

These figures may be reduced, of course, to a quarterly or monthly basis.

Theoretically these rates seem to be all that might be desired and for the larger cities should be both efficient and economical, but the question in my mind is, at what stage in its development and growth is a city justified in metering absolutely all services. I shall use Salisbury as an illustration, because I am more familar with the situation there than elsewhere. Salisbury has a large territory that at present has no sewerage facilities, but which is served with water. These are practically all one spigot services and use a small amount of water, so it has been our practice not to meter this class of service. At present we have 1633 metered services and 670 flat rate services or 29 per cent of the total not metered. Of course all towns and cities have this condition to some extent, but the larger the city the lower the percentage.

It would cost Salisbury nearly $9000 to make the change and, if the rate were based on the present meter rates, the revenue would be considerably less from this class. Each town has its own characteristics and Salisbury's actual per capita consumption is low, over 50 per cent of the metered services using less than 20,000 gallons

per year. In my humble opinion, our present system of a minimum rate, allowing the use of the amount of water that the meter rate pays for, is best suited to our present conditions. We can at least handle the situation with less outlay of money and as a result with lower rates.

Possibly the question of justice to the smaller consumer may have some argument, but as long as our minimum is 75 cents a month the matter cannot be very serious.

The minimum system, with a monthly or quarterly allowance, is in such general use that it needs no discussion. The fact that it has stood the test so long, warns us that we should weigh all the facts before making a radical change.

Of course, where a town is already 100 per cent metered and feels justified in keeping up the practice, the rates as recommended by the Committee might be put into effect with satisfactory results.

To my mind it is impracticable to try to establish a Standard Rate System in the smaller towns as long as the conditions in the various communities are any thing but standard. However, I see no objection to using the three classes of rates as adopted by the New England Association. There is much more argument in favor of that plan than the one in which we have from five to fifteen different rates. Possibly for some towns the yearly allowance may be high but that might be easily adjusted.

If we prefer to continue the minimum charge system and adopt the three rate method, it would be comparatively simple to figure out what the minimum should be after we know just how much revenue we require from this source.

You notice I said it was *comparatively* simple, because as we all know there is nothing simple about trying to establish water rates, if we really do justice to the situation. The minimum or service charge, as the case may be, is the determining factor, because the actual cost of handling of water is low. If our minimum seems to be high when compared with other places, it cannot be helped provided it is just and fair.

The water works superintendent is best qualified to establish rates, because that is an important part of his business. He at least knows what is wrong with his system and if he confers with his fellow superintendents he soon finds the things to avoid. The proper thing for the superintendent to do before trying to establish a new rate is to *visit* other superintendents who should be able to help him, instead of writing to them for a copy of their rates.

REPORT OF COMMITTEE NO. 4, ON COLLOIDAL CHEMISTRY, OF THE COUNCIL ON STANDARDIZATION

The Council on Standardization referred for report to the Committee on Colloidal Chemistry the questions of the determination of hydrogen ion concentration and its significance in the management of water works. A complete report of the work of this Committee was presented to the Council on April 13. In the present paper, the Committee presents its work to the Association in summarized form.

The questions referred to the Committee are concerned with the practical significance of hydrogen ion concentration determinations in connection with coagulation, softening, filtration and corrosion. In view of the expositions of physico-chemical theory which have appeared already in recent papers[1] before this Association and elsewhere, your Committee has felt justified in presenting a summary of research data collected by its members or supplied by friends, rather than adding to the theoretical discussion of the method. The Committee realizes that, unless correlated with certain equilibria, hydrogen-ion concentration has little or no significance and is by no means a panacea for water treatment troubles, although it is one important factor in the several which enter into every problem of water quality and treatment.

[1] Relationship of Hydrogen Ion Concentration of Natural Waters to Carbon Dioxide Content, R. E. Greenfield and G. C. Baker, Jour. Ind. & Eng. Chem., Vol. 12, 989–991, Oct., 1920.

Residual Aluminum Compounds in Filter Effluents, Abel Wolman and Frank Hannan, Chemical and Metallurgical Engineering, Vol. 24, No. 17, Apr. 27, 1921.

The Significance of pH in Drinking Water and Particularly for the Business of Water Supply. A. Massink and J. A. Heymann, translated from the Dutch by Mr. Hannan and prepared for publication by Mr. Wolman. This Journal, Vol. 8, No. 3, May, 1921.

Further Observations on pH in Natural Waters, Abel Wolman and Frank Hannan, Chem. and Met. Eng., Vol. 25, No. 11, Sept. 14, 1921.

Significance of Hydrogen Ion Concentration in Water Purification, H. P. Eddy, Journ. N. E. W. W. A., Vol. 34, No. 4, P. 385.

Application of Colloidal Chemistry to Study of Filter Effluents, Malcolm Pirnie, This Journal, Vol. 9, No. 2, March, 1922.

Since hydrogen ion concentration is usually expressed as the logarithm of the reciprocal of the concentration,—log. $\frac{1}{H^+}$ = pH, known as the pH value, this term will be used in this report.

RELATION OF pH VALUE TO OTHER FACTORS

That there is a mathematical relation between the free carbon dioxide, the bicarbonate alkalinity, and the pH value of a water has been stated by Tillmans,[2] Massink and Heymann,[3] and Greenfield and Baker.[4] These formulae are as follows:

$$H^+ = \frac{3\ CO_2}{\text{Bicarbonate Alkalinity (as } CaCO_3) \times 0.61} \text{ (Tillmans)}$$

$$H^+ = 6 \times 10^{-11} \times \frac{\text{Bicarbonate } CO_2}{\text{Carbonate } CO_2} \text{ (J. Heymann)}$$

$$H^+ = \frac{4\ CO_2 \times 10^{-7}}{HCO_3^-} + 1 \times 10^{-8} \text{ (Greenfield \& Baker)}$$

Since the data for substitution in the various formulae are obtained by two titrations, the end points of which are judged by "color memory," the results may not be as accurate as those obtained by the direct determination of the pH value colorimetrically, where the color is matched against a carefully checked standard. Greenfield and Baker, using their formula, computed the pH values for fifteen waters of Illinois, from both ground and surface sources, and found that in only one case was the difference between the determined and calculated pH value greater than 0.3, while the mean variation was about 0.1, the wider variations occurring in the cases of low bicarbonate content. These workers made 65 determinations in all.

A. Wagner and Linn H. Enslow of the Virginia State Department of Health[5] have kindly furnished this Committee with the results of 95 determinations of pH value for waters supplied by purification plants to 17 Virginia cities. These results are now in print. They give the pH values in raw, coagulated and filtered waters computed by Tillmans' formulae from the determinations of bicarbonate alkalinity and free carbon dioxide, and compared with the pH values

[2] The Chemical Examination of Water and Sewage, 1915.

[3] This Journal, Vol. 8, No. 3, May, 1921.

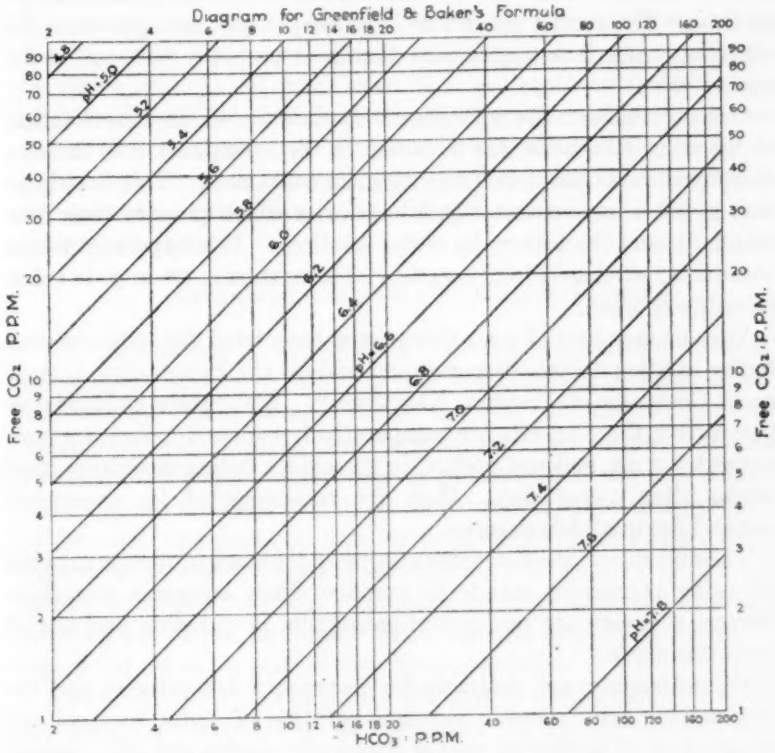
[4] Loc. cit.

[5] Applied pH, A Study of Its Merits in Practical Filter Plant Operation, This Journal, Vol. 9, No. 3, May, 1922.

determined colorimetrically. In 33 out of the 95 tests made the observed pH values failed to check the calculated by more than 0.10. In other words, 65 per cent. of the samples showed calculated values which checked closely with those observed.

Mr. Ellms, of the Committee, finds that the computed and observed values do not agree so closely, but vary from 0.3 to 0.6.

All of the experiments indicate that, when two of the three factors



are known, the third may be determined with an accuracy sufficient for purification plant control. When employing a formula, the analyst should use the two determinations of the three which will determine the third most accurately. With ground waters containing iron, caution should be used in interpreting the free CO_2 determinations. At Cleveland it would have been more accurate to determine the pH value and the alkalinity, and to calculate the free CO_2.

The rules suggested by Wagner and Enslow[5] are recommended for

accuracy, when using Tillmans' formula. These rules should be used in connection with one of the formulae plotted on a logarithmic chart, with the values of free carbon dioxide as abscissae, of pH as ordinates, and of alkalinity as a series of straight lines. The relations between these various factors are logarithmic. The rules are not repeated here, since they are to be found in the original text.[5]

Your Committee is agreed that the determination of the pH value of any water is feasible by either the colorimetric or the potentiometer method. The former procedure is so simple and the apparatus for carrying it out is so convenient that it is probably best suited for general use.

One objection to the colorimetric method lies in the deterioration of the color standards due to fading or the precipitation of the dye stuff by silicates dissolved from the glass containers. This deterioration is not a serious factor in laboratories which prepare their own standards and check them by buffer solutions. It is important where standards, purchased from commercial laboratories, are kept in tubes of ordinary glass.

Various members of your Committee have tried the indicator and buffer solution tablets prepared and sold by the Pyroelectric Instrument Company of Trenton, New Jersey. While the standards prepared from these tablets are comparatively expensive, they are convenient for use and are preferable to rapidly fading standards used weeks after preparation. They are recommended for occasional use and for small laboratories.

The difficulties due to deteriorating standards might also be avoided by using permanent standards prepared from inorganic materials. Several chemists are now investigating the preparation and use of such standards.

Potentiometers are desirable for permanent laboratories and for determining the hydrogen ion concentration of turbid and colored waters and of industrial wastes frequently discharged into natural waters. Potentiometers are now available which give a continuous record of the hydrogen ion concentration of a water. This record, with determinations of either free CO_2 or bicarbonate alkaliinty or both, would greatly facilitate the control of purification plants.

The Committee has collected a mass of detailed data which is too voluminous to be presented in this report. Material has been received from Columbus, Ohio, Little Falls, N. J., Chapel Hill, N. C., Cleveland, Ohio, Minneapolis, Minnesota, Baltimore, Maryland,

and various plants in Virginia, Illinois and New England. These data cover a wide range of conditions. The preliminary conclusion which may be drawn from the statements of those sending in the data is that the results of hydrogen ion concentration determinations are considered to be more useful in connection with soft, colored waters, than with hard, alkaline waters.

In the work with soft, colored waters, it would appear that the coagulation of the coloring matter is at an optimum when the pH value is low, sometimes as low as 5.5, but generally less than 6.0. On the other hand, the effluent resulting from such treatment is corrosive, and the pH value must be raised again by the addition of an alkali, such as soda or lime. It is impracticable to add soda before filtration because it increases the pH value. Chlorine may be used before filtration, where its effect, it is suggested, is to reduce the pH value, to oxidize some of the organic matter and to bring about easier coagulation.

THE SIGNIFICANCE OF pH IN COAGULATION

The coagulation of suspended or dissolved materials in a water is not a simple problem. While in any single sample of water there is undoubtedly a definite range of hydrogen ion concentration for maximum precipitation, under given conditions of free carbon dioxide and bicarbonate alkalinity, other factors, some of which are not chemical, enter into the problem. Of these, temperature, rate of mixing, degree of dilution, concentration and kinds of electrolytes present, nuclei, organic acids, and the amount and character of the suspended matter greatly affect precipitation. Furthermore, there are specific reactions between aluminum hydroxide and color and suspended matter, on which the pH value may or may not throw light.

The possibility of use of pH for the control of coagulation processes has been the subject of much discussion. It has been stated[6] that, if alum-treated waters were adjusted to a pH of 7.0, the approximate conditions for the optimum precipitation of aluminum hydrate would result. As a matter of fact, the iso-electric point for the coagulation of all waters by sulfate of alumina is not the same. Buswell and Greenfield[7] have shown that this constant alone is not sufficient for the determination of the optimum condition for coagulation. While the H-ion concentration is important, it is not the sole determinant.

[6] H. P. Eddy, Loc. cit.
[7] Science, N. S. Liv. No. 1408, p. 693.

In 1901, one of us[8] determined by experiment the amount of sulfate of alumina required to decolorize a New Orleans deep well water having an average color of 208 and an average alkalinity of 408. It required 10 g.p.g. of sulfate of alumina to coagulate this water before and 2 g.p.g. after it was neutralized with H_2SO_4. In other words, the lowering of the pH greatly accelerated coagulation.

It is probable that the minimum solubility of aluminum hydrate is closely related to its iso-electric point and is dependent upon the relation between its acid and base solubility constants. Mathematical calculations for additions of aluminum hydrate to pure water seem to indicate that the point of minimum solubility is on the acid side, considerably below pH = 7.0, provided we know the acid and base solubility constants accurately enough to base such a calculation upon them.

For several years it has been known that, at certain New England water purification plants, with waters having alkalinities less than 30 p.p.m. and colors ranging from 30 to 80 p.p.m., the best coagulation may be obtained when the ratio of the free CO_2 to the alkalinity is high, i.e., when the pH constant is low. In some of these cases the pH value of the filtered water is less than 6.0.

Addition of soda to these New England waters to reduce corrosion must be limited or the precipitate will redissolve. Consequently when it is necessary to maintain an alkalinity in the effluent as high or higher than that in the influent, soda must be added to the filtered water. Baylis[9] has shown that at Baltimore coagulation is best when the pH is below 7 and above 5.6, and that an addition of lime to the effluent is necessary to reduce corrosion.

Wagner and Enslow[10] have formulated in Virginia certain "laws of coagulation" which should be observed where artificial alkalinity additions are necessary. They believe that waters requiring artificial alkalinity should be carefully treated to provide an alkalinity of the coagulated water 3 to 5 parts less than that of the raw water. This corresponds to a pH value of from 5.7 to 7.0, depending upon the water.

Your Committee believes that the importance of hydrogen ion concentration tests is established, but that its practical value varies with the water and the use to which the water is put. While satis-

[8] Trans. Am. Soc. C. E., 66, 168.
[9] This Journal, Vol. 9, No. 3, May, 1922.
[10] Loc. cit.

factory filter plant control may be secured in nearly all, if not in all cases, by existing methods, the use of pH values will facilitate greatly the operation of many filter plants, particularly those treating surface waters of low alkalinity, low carbon dioxide and high color.

THE IMPORTANCE OF pH IN CORROSION

That acid waters corrode iron and other metals used in distribution systems more readily than alkaline is well known. It is unfortunate that the treatment of many waters results in an effluent which is highly corrosive,—that is, a water low in alkalinity and pH value and high in free CO_2 and dissolved oxygen.

As shown by Thresh,[11] the most important factor in corrosion is oxygen, while the free CO_2 and pH values are contributory factors. One of the most corrosive waters in the vicinity of Boston is the effluent of the deferrization plant supplying Brookline. This water has a pH value ranging from 6.8 to 7.1. It contains, however, 10 parts of oxygen and 7.5 parts of free CO_2 per million, with only a small amount of organic matter (oxygen consumed = 1.02 p.p.m.)

Other corrosive waters containing high free CO_2 and oxygen usually have low alkalinities and consequently low pH values.

The remedy for corrosion is usually to increase the concentration of the OH ions thereby increasing the pH value. This may be done by the addition of an alkali. In the case of purification plants, this should be added to the filtered water. Experience at Milford, Mass.[12] indicates that corrosion of lead services may be largely prevented by reducing the free CO_2 in the filtered water to 1 p.p.m. or less by the addition of lime. At times the pH value of this water, after treatment, approaches 8.0.

Wagner and Enslow state that the free CO_2 in treated waters should be reduced to 2 p.p.m. They recommend aeration for this purpose, but reduction to such a low point may rarely be accomplished without the addition of a small dose of alkali.

Conclusion.

In the determination of hydrogen ion concentration, water works operators have a new weapon to use in combating problems of water treatment.

[11] Notes on the So-called Action of Water on Lead, John C. Thresh, The Analyst, July, 1921.

[12] Lead Poisoning by Water and Its Prevention, R. S. Weston, Journ. N. E. W. W. A., Vol. 34, No. 4, Dec., 1920.

The method demonstrates again, but in a more readily appreciated way, that a water treated for optimum coagulation may exert, when filtered, its maximum corrosive action on metals. It confirms the practice of adding alkali to certain waters after filtration rather than before. While this and other results of the use of this method justify at this time no material modifications in water works design or practice, your Committee feels that its use will throw much light upon current practices and may indicate eventually departures in processes of economic advantage. At least, the adoption of pH tests gives promise of leading to a more rational treatment of waters.

ROBERT SPURR WESTON, *Chairman*,
LEWIS I. BIRDSALL,
A. M. BUSWELL,
J. W. ELLMS,
F. W. GREEN,
FRANK E. HALE,
FRANK HANNAN,
H. D. HATFIELD,
CHARLES P. HOOVER,
ABEL WOLMAN.

EQUIPMENT AND SHOP FACILITIES FOR MAINTENANCE OF WATER WORKS SYSTEMS[1]

By George E. Cripps[2]

Having been asked to describe some of the shop facilities and equipment used in the maintenance and repair division of the water works distributing system of Rochester, N. Y., I shall endeavor to give you some idea of what we had in the way of equipment thirty-eight years ago, when I was first employed and what we have today. Before referring to that subject, however, I should like to take a few minutes to compare the water works with other municipal departments.

When a stranger visits a city and is taken in hand by a friend or a city official and is shown the well-kept streets, the beauties of our parks, our police and fire departments, our school buildings and other points of civic interest, he seldom or ever hears mention of the water works department, no matter how efficient it may be. The reason for this omission may not be a lack of interest, but because most of our work is covered up and does not appear on the surface, but you water works men know that we do not want it to show on the surface, because when it does there is additional work ahead for you and me.

Consider another view, a person goes to fill the tea kettle for breakfast, turns the faucet and gets no water, or the man goes to his factory to begin the day's work and on arrival is informed that there is no water and consequently no work. A condition as shown in figure 1 may have been the cause of the shut down of the factory and neighborhood. The sooner we restore normal conditions, the sooner will the factory begin operation and the inconvenience to the neighborhood be overcome. It is only when something like this occurs that the maintenance division of the water works comes to the front. Should the stranger and his escort happen to be passing where a break has occurred, then perhaps the water works would get favorable mention.

[1] Presented before the Philadelphia Convention on May 18, 1922.

[2] Superintendent, Water Works Repair Department, Rochester, N. Y.

I shall now give you some idea of what our shop consisted when I began to work for the department. Our space was limited and our equipment the crudest. Transportation facilities consisted of two

FIG. 1. BROKEN 36-INCH WATER MAIN

horse drawn wagons, a push cart and a wheelbarrow. Many times I had to act in the dual capacity of horse and driver. Today we have 26 automobiles and trucks to serve our needs.

In 1884 we had about 143 miles of pipe, today we have over 500 miles. At that time we had about 1,390 hydrants, today 6,064. Valves in 1884 numbered 1,567, today 10,970. About 300 meters were in use then, today 45,000 (Rochester is 100 per cent metered). Rochester is not standing still and we all must realize that, after a water works plant has been in operation for 50 years, its need for modernization is urgent.

Another piece of equipment which I consider most essential, especially where cities, like Rochester, often get zero weather is a portable boiler. Our portable boiler is a coal burner and carries about 60 pounds of steam. You may ask what good a boiler like that is. For instance, you have to shut off a number of gates as in the break shown in figure 1. It was near zero at the time. Two of these boilers thawed away the snow and ice that covered the boxes in much less time than it would take to break through with pick and shovel. We use them also to thaw out the box and loosen up the head of the gates. I often find gate box covers frozen solid and even the heads of gates so that they cannot be operated. We use them also to thaw out frozen hydrants. In freezing weather a boiler is sent to every fire to help the Fire Department loosen their hose from the frozen pavement, to thaw out their hose connections and to put the hydrants back into operating condition. It is my opinion that, for these purposes, one of these boilers will do more work than a dozen men.

A valve opening and closing machine was bought by the Department in January, 1921, and it has been a great help to us already. I believe no city should be without one if they are not equipped with Dean Controls. Mr. Mitchell of Detroit showed and explained its merits at the Cleveland Convention, so I will not take any more time except to say that we keep this piece of equipment for emergency only. (See JOURNAL, March, 1922, page 172.)

How many people in your city or mine know or ever think of the forethought and the constructive work that was done by our engineers in bringing water to supply a large city, how many know the source of their water supply, the means employed in delivering it, the vast amount of detail work in connection with it? I dare say not many. Most people are content simply to turn the faucet and leave it to us to do the rest. I have often thought that it would be a good idea to educate the school children as to where the water they drink comes from and how it is distributed and made available for their

use. Few people know of the constant demands made on the water department. I think you will all agree with me that we are not 8, but 24, hour per day men.

Where are most of the repair and meter shops located? I am afraid there are a great many where they should not be. I remember well ours a number of years ago. We were located first in the basement of the City Hall. From there we moved to an upper floor in a poor building, then to another place not much better, but ten years ago the City of Rochester secured a desirable site for the Water Works Repair Division, modern buildings were erected and our plant

FIG. 2. OFFICES AND REPAIR SHOP OF ROCHESTER WATER WORKS

today will stand comparison with any other in the country. A great many city officials think that any old place is good enough for water works shops. After serving in my Department for 38 years, I maintain that the water service department, which is serving every man, woman and child in the city, every minute of the day and night, is a revenue producer and an asset on the credit side of our tax budget, should be adequately housed.

Figure 2 shows our plant as it is today. These buildings house the repair shops, meter repair shops, blacksmith shops and garage. The main building is 212 ft. long and 42 ft. wide, the front is used for office purposes, where all shop records are kept and it is fireproof. The lower floor is used for meter service and the upper for general repair service.

We are all having the same trouble, I have no doubt, with hydrants being broken by automobiles. A device for welding was invented by us. (Figure 3.) You may readily see that it is homemade. Your attention is called to the rod running through the centre of the hydrant. A thread is cut on each end with a plate and lock nut to keep the barrel in alignment. You will also notice the four holders. They are used to adjust the height. The rollers, on which the hydrant revolves, relieve the strain on the hydrant barrel.

We had a 4-inch Matthews hydrant broken by an automobile that had been in constant and uninterrupted use for 46 years. I had it removed for repairs. My men asked me what to do with it. I

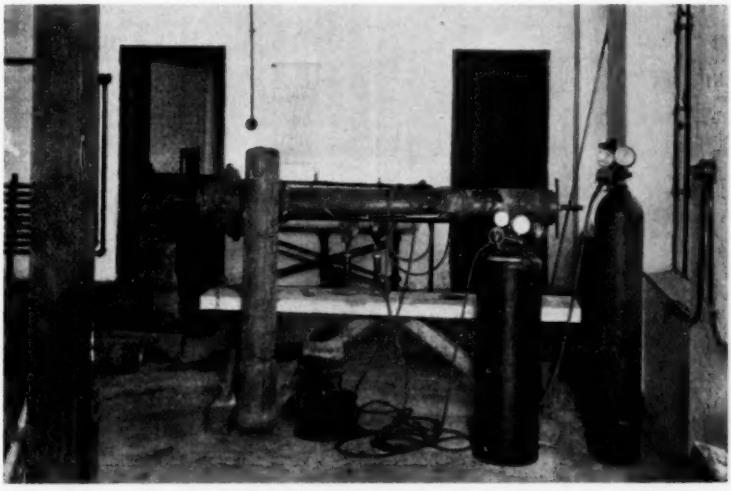


FIG. 3. DEVICE FOR WELDING FIRE HYDRANTS

told them to weld it, if the stock would stand it. This was done and today this same hydrant is again is use and will serve us I believe another 46 years, unless it is again struck by an automobile. I am proud to say that we have a great many hydrants as the above, that have been in use the same length of time and are giving good service today.

A good shop like a good ship needs competent men to man it. In this respect our calling differs from other lines of work. If a contractor needs masons or carpenters, he hires men skilled in those branches of trade. When additional men are needed in our branch, we cannot go into the market and secure competent water works

FIG. 4. PIPE YARD IN REAR OF MAIN BUILDING

FIG. 5. INTERIOR VIEW OF REPAIR SHOP

repair men. It is necessary for us to educate our own men in the various phases of work which we are called upon to perform. In our Department the men are classified as office men, plumbers, tappers, meter setters, meter repairers, day-service men, night-service men, blacksmiths, chauffeurs, stockkeepers and toolmen. Since we must educate the men we have in the different kinds of work they are called upon to do, the prime requisite is to get young and reliable men, to encourage and instruct them, to let them know that we have an interest in their future and that some day they will be the men on whom the responsibilities of caring for the mechanical needs of the Department will rest.

Now just a word about cast iron pipe. I think the first pipe made in this country was made here in Philadelphia. If there is one thing that may be buried underground and retain its usefulness over a long period of time, it is the good old cast iron pipe. In all my experience I can recall only a few instances where cast iron pipe gave out on account of defective material. When trouble does come, you generally find that the fault was in the "laying" and not in the "making".

In connection with cast iron pipe the question arises, what is the best material to use to caulk a joint. We all have used pig lead for this purpose for a long time, but I for one have become converted to the use of "Leadite". Judging from the good results that I have had since I began using it, I believe that in a few years at the most very little pig lead will be used, but instead you will use "Leadite" or some other material of a similar nature. I confidently believe, too, that when you do, you will get fewer leaks, have fewer joints blowing out and be able to lay mains not only more cheaply, but better than ever before.

Several good instruments for locating leaks have been invented. Those that I have used have been helpful, but there is still room for improvement. The best instrument that I know of to locate a leak is the man with experience.

A drinking fountain has been designed by me with the assistance of one of my plumbers. The 18th amendment was not the incentive, but the desire to provide drinking water during the summer months to the people who throng our busy streets. We now have a large number of them in use, they are much appreciated and their cost is nominal.

In all that I have said, I have tried to lay stress on the importance of having good men, good equipment and good shop facilities. Now I wish to say a word about the tools we use. In every well-governed and regulated shop there should be a place for every tool and every

FIG. 6. DRINKING FOUNTAIN ON PUBLIC FIRE HYDRANT

tool should be kept in its place. There should be a place for emergency tools and these tools should be used only for emergency. The best tools and the best materials are provided, because in our work, as in all others, cheap tools and materials are the most expensive in the end.

GROUND WATER HISTORY AT BLOOMINGTON, ILLINOIS[1]

By Donald H. Maxwell[2]

There are a few simple lessons to be learned from the water supply experience at Bloomington, Illinois, which make it seem worth while to record briefly the history of that experience.

Bloomington is situated in the glacial drift area of central Illinois and is underlaid, in part, by good water bearing gravels. Extensive well drilling and pumping experience of various interests, extending over the last forty-five years, have served to define the zones of good yield to a small area near the business district of the city and to a strip ½ mile or more in width underlying Sugar Creek and extending along the northwest boundary of Bloomington for several miles in a general northeast and southwesterly direction (fig. 1). The latter area is the more important source. The main water horizon is a gravel bed of excellent water carrying capacity from 10 to 30 feet thick. This deposit is about 50 feet below the surface and is overlaid principally by clay (fig. 2).

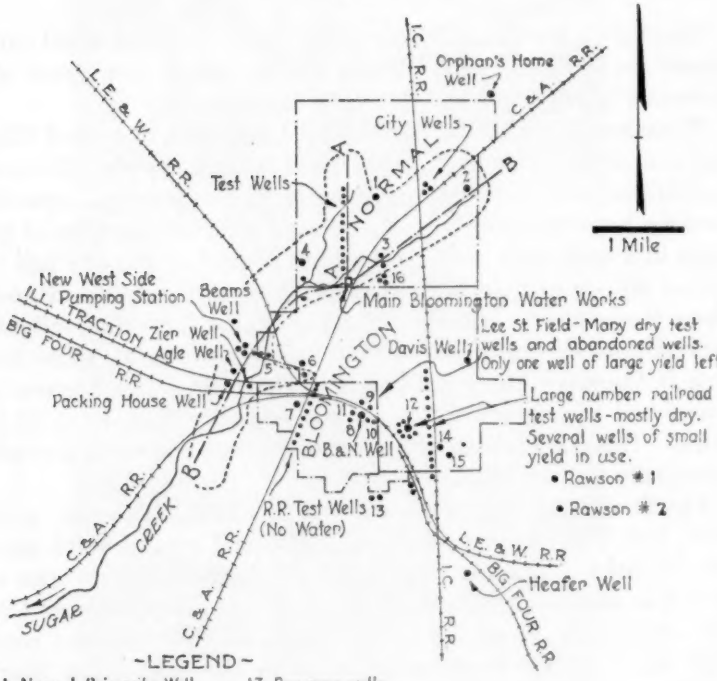
The first city water works was built in 1875. The city, at this time, had a population of about 16,000 and ranked third among interior cities of Illinois. The initial development was an open well 40 feet in diameter by 28 feet deep, constructed close to Sugar Creek just outside the Bloomington city limits, at the northwest corner. This site is at the southeasterly edge of the main water bearing gravels above mentioned. The ground water at this time stood within a few feet of the surface and caused considerable difficulty in building the well, which was on this account not carried to the depth originally intended. By 1886 the supply from this well had become insufficient and in that year an unsuccessful attempt was made to deepen the well by sinking a steel cylinder of 8 feet diameter in the bottom of the large well. In 1887 six tubular wells were drilled along the east bank of Sugar Creek and two of these were temporarily connected up and pumped into the open well in order

[1] Presented before the Illinois Section meeting, March 29, 1922.

[2] With Alvord, Burdick, and Howson, Chicago, Illinois.

to supply the main pumps during water shortage of that summer. Later all six wells were connected by a sixteen inch suction line and umped into the open well.

WELLS AND WATER BEARING GRAVELS
IN VICINITY OF BLOOMINGTON, ILL.
Figure 1

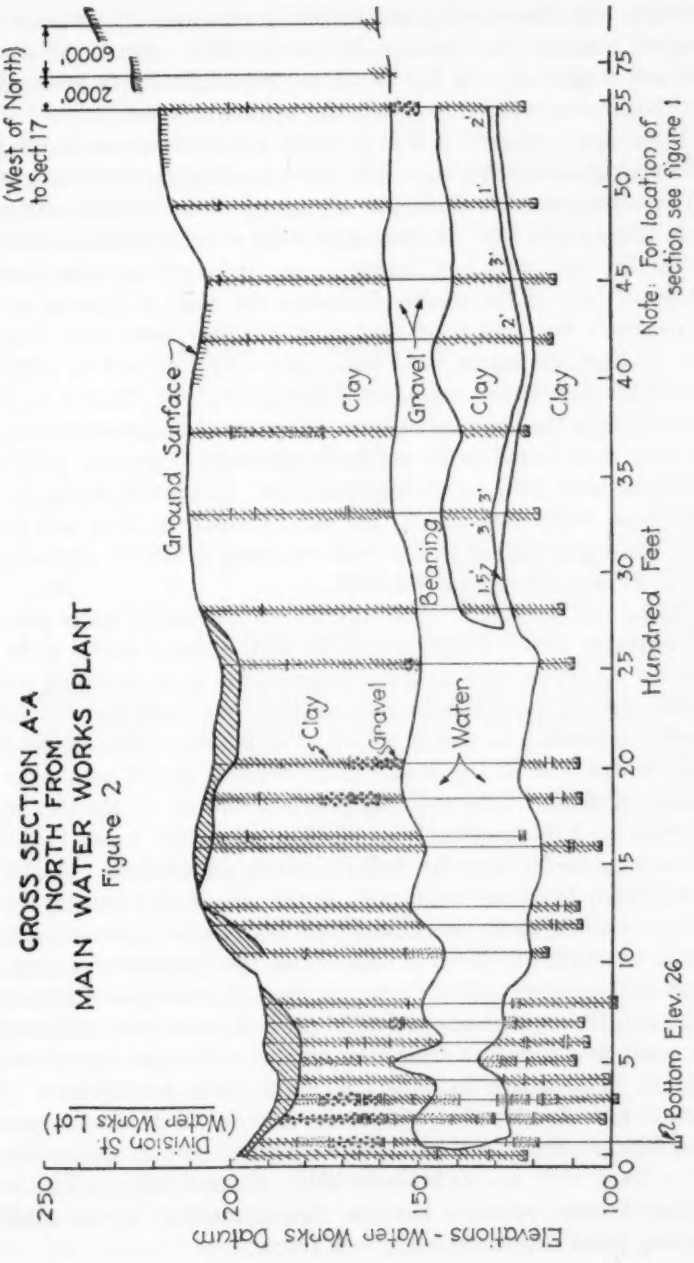


-LEGEND-

1 Normal University Well
2 Dillon test well
3 City test wells
4 Cottage Ave. test wells
5 City test wells
6 Brick Plant well
7 Candy Factory well-dry
8 C. & A. Lee St. well-dry
9 Ice Plant wells
10 Big Four wells-small yield
11 City well-dry
12 Big Four roundhouse test wells-mostly dry
13 Brewery wells
14 I.C.R.R. wells
15 City test well 1920-poor yield
16 Canning factory wells-no good gravel

Approximate boundary of good water-bearing gravel. Exploration too meagre to accurately define limits.

The water supply still being short, six more tubular wells were sunk and connected by a suction line laid 16 feet deep and the main pumps lowered to this level. The suction line to the first


CROSS SECTION A-A
NORTH FROM
MAIN WATER WORKS PLANT
Figure 2
Davis Well
(West of North)
to Sect 17
.0009'
.0002'
Ground Surface
Clay
Gravel
Clay
Clay
Gravel
Bearing
Water
Clay
Gravel
Clay
Water
Division St.
(Water Works Lot)
Bottom Elev. 26
Elevations - Water Works Datum
250
200
150
100
0
5
10
15
20
25
30
35
40
45
50
55
75
Hundred Feet
Note: For location of
section see figure 1

six wells was also lowered to 16 foot depth and all the wells were pumped through this suction line until 1895. The original open well was deepened to 48 feet in 1894. The difficulty of construction in the water prevented carrying the work any lower.

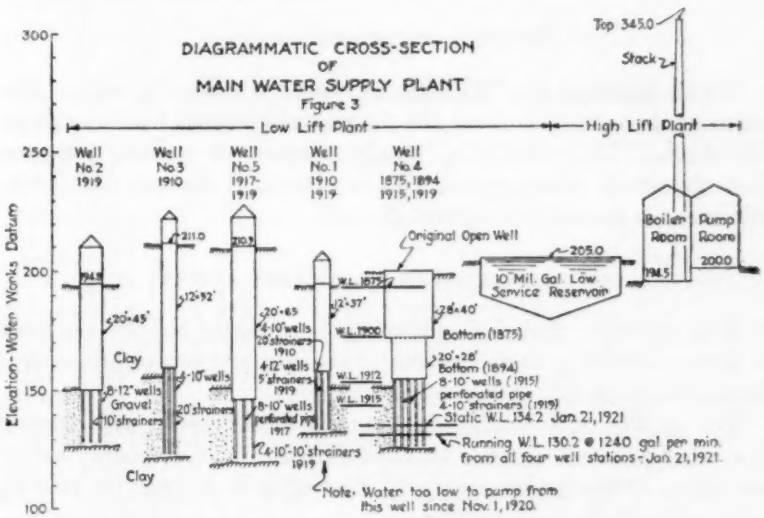
These improvements failed to avert a serious water shortage in 1894 and again in 1895, when the water level had receded 33 feet.

The attempt to continue the supply by direct suction was given up in favor of air lift. In 1895 new wells were drilled and equipped for air lift pumping, but, owing to the recovery in water level to within 17 feet of the surface following the rains in December, the compressors were not used that year, but they soon came into use and by 1891 the water level was again very low and in 1902 was too low for satisfactory operation of the air lift. In 1902 five strainers were pulled in the hope that cleaning them would improve the supply, but they were found to be not badly choked. Two new wells were drilled in that year to replace wells lost in pulling strainers. In 1904 three wells were added, the same number in 1905 and one in 1906, making a total of eleven wells operated by air lift at that time. One more was subsequently added.

During the summer of 1906 the city experienced a water shortage and again in 1909. Prior to this, all of the water works wells had been sunk over an area of a few acres at the main pumping station at one edge of the water bearing gravels. In 1909 the city drilled a well on South Lee Street about 1½ miles southeast of the main water works and in the small water bearing gravel area near the business district. This well was pumped directly to the city mains and was used intermittently until 1910, when the water level here had receded so far that the well had to be abandoned. No further development has been attempted by the city in this locality.

The air lift system was abandoned in 1910 in favor of pumping groups of wells by direct suction from the bottom of pump pits about 50 feet deep. There are now five of these pits which range from 12 to 20 feet in diameter. The pits are located several hundred feet apart and there are from four to twelve wells in the bottom of each pit. Pumping is by means of motor driven centrifugals. This plant, as now developed, is shown on figure 3. Within ten years the water level at this plant had further receded to a point sufficiently low to leave well no. 1, built in 1910, without water. The water shortage became so acute that the development of a new auxiliary pumping plant was undertaken last year.

The auxiliary pumping plant at West Market Street is about 1½ miles southwest of the main station and just outside the city limits along the banks of Sugar Creek and probably taps the same water bearing stratum as the main station. Four new wells have been put down at this plant and two of them equipped with vertical shaft pumps which deliver water to a small reservoir, from which it is repumped by motor driven centrifugals to the city mains. This plant has tided the city over a threatened water shortage during the past two years.



Although considerable exploration of the water bearing gravels at Bloomington was made by the city in 1910 there does not appear to have been at any time in the course of the development of this water works a successful plan worked out for the development of this source that would take proper account of the limitations of the supply as developed over a small area. The very excellent carrying capacity of the gravels which produces wells of large yield appears to have been a misleading factor. The mistake has been made of attempting to follow the water level down with developments of large capacity concentrated in a small area and capable of exhausting the tributary gravel storage in a few years.

The result of this policy has been the necessity of abandonment every few years of investment in wells, pipe lines, pump pits and

pumping equipment still good but made useless by the continual recession of the ground water. Even greater loss has probably been occasioned through the poor efficiency of low lift pumping equipment continuing in operation under adverse conditions. The motor driven centrifugal low lift pumps were found last year to be operating at an overall efficiency of only 15 per cent. Aside from the inefficient operating condition and recurring financial loss from useless plant the city has seen in the process of outgrowing first one development and then another, repeatedly on the verge of water famine.

HARDNESS OF PRESENT SUPPLY

The hardness of the Bloomington water is unusually high. The permanent hardness is about 300 p.p.m. and the total hardness about 700 p.p.m. The water is so poorly adapted to washing purposes that the use of cistern water, with its attendant expense and inconvenience, is general throughout the city.

CITY HANDICAPPED BY PRESENT SUPPLY

It is probable that the excessively hard water supply has been a distinct handicap to the growth of the city and probably accounts largely for its lack of industrial development.

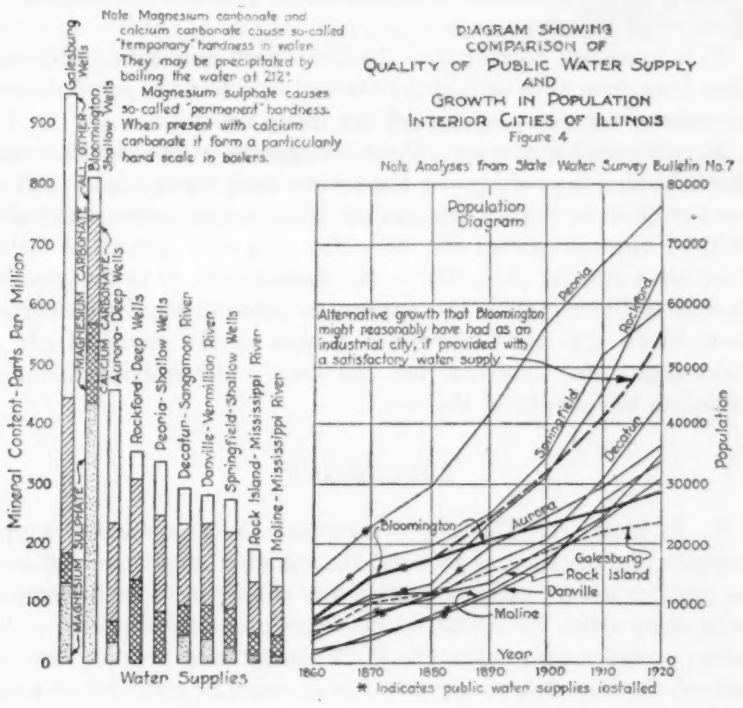
The growth of Bloomington compares unfavorably with that of the other principal interior cities of Illinois. This is plainly shown on figure 4 where the growth of Bloomington appears in striking contrast to that of other cities.

In 1870 Bloomington was twice as large as the average size then of the five cities of Aurora, Danville, Decatur, Moline and Rock Island. Today these cities not only average 25 per cent larger than Bloomington, but are now growing at a much faster pace. They have increased nearly fivefold, while Bloomington has barely doubled in fifty years. Bloomington did not fall behind Springfield and Rockford in rate of growth until about 1880, about the time that industrial development in this region had its first impetus. Peoria, which in 1870 was barely half again as large as Bloomington, is today over two and one-half times as large.

In the essentials to growth, other than a favorable water supply, Bloomington does not appear to be particularly lacking. The city is centrally located in a rich and productive agricultural region and is well within the boundaries of the Illinois coal field. It is situated

midway between Chicago and St. Louis on a main line railroad connecting these great industrial centers, is served by three other railroads, and has a total of ten railroad lines radiating from the city in different directions, in addition to an interurban line running west and one south. This general region is one preëminently of industrial and manufacturing development.

Bloomington in spite of these advantages and an early start is practically without industrial development other than the Chicago


Note Magnesium carbonate and calcium carbonate cause so-called "temporary" hardness in water. They may be precipitated by boiling the water at 212°.
Magnesium sulphate causes so-called "permanent" hardness. When present with calcium carbonate it form a particularly hard scale in boilers.
DIAGRAM SHOWING COMPARISON OF QUALITY OF PUBLIC WATER SUPPLY AND GROWTH IN POPULATION INTERIOR CITIES OF ILLINOIS
Figure 4
Note Analyses from State Water Survey Bulletin No.7
Mineral Content - Parts Per Million
Water Supplies
Galesburg Wells
ALL OTHER
Bloomington Shallow Wells
MAGNESIUM CARBONATE
CALCIUM CARBONATE
MAGNESIUM SULPHATE
Aurora - Deep Wells
Rockford - Deep Wells
Peoria - Shallow Wells
Decatur - Sangamon River
Danville - Vermillion River
Springfield - Shallow Wells
Rock Island - Mississippi River
Moline - Mississippi River
Population Diagram
Alternative growth that Bloomington might reasonably have had as an industrial city, if provided with a satisfactory water supply
Peoria
Rockford
Springfield
Decatur
Aurora
Bloomington
Galesburg
Rock Island
Danville
Moline
Year
Population
1860 1870 1880 1890 1900 1910 1920
* Indicates public water supplies installed

and Alton Railroad shops. There are, of course, the usual utilities and purely local industries, but practically no manufacturing.

A plentiful supply of good water at moderate cost is essential to a modern large community. This is what Bloomington lacks. Figure 4 shows the mineral content of the public water supplies of the cities whose growth we have compared with that of Bloomington. It shows that the mineral content of the Bloomington water is more than twice that of these other city supplies.

When we compare the relative amounts in these supplies of the various salts that cause so-called "hardness" in the water, the contrast is still more unfavorable to Bloomington. Of these salts, magnesium sulphate, which forms hard scale in boilers, is particularly objectionable. It should be noted that the Bloomington public water supply contains more magnesium sulphate than the total mineral content of any of these other water supplies, excepting only Aurora. In contrast with the Bloomington water, the content of the objectionable magnesium sulphate is practically negligible in these other supplies.

It is important to note that the fairly hard municipal water supplies from deep wells both at Aurora and Rockford are supplemented by softer river water for part of the industrial use.

It is interesting now to compare the growth of Bloomington with that of Galesburg, which also has a very hard water supply, not as hard or quite as objectionable as the Bloomington water, but higher in total mineral content (fig. 4). The very slow growth of Galesburg has a striking similarity on the diagram (fig. 4) to the retarded growth of Bloomington, and appears to substantiate the conclusion here drawn that the unfavorable quality of the water supply of Bloomington for industrial use has been a determining factor in retarding the growth of the city.

DISCUSSION

L. R. Howson:[2] This paper regarding the Bloomington supply suggests the question as to what Bloomington might have afforded to pay for a soft and adequate water supply in order to compete with other cities for industrial development. Investigation of the entire water supply situation at Bloomington a year or two ago proved the fact that an adquate supply could be provided at a cost of $1,000,000 or $1,250,000, that is $30.00 or $40.00 per capita. That is a high price compared to the average cost of developing water supplies around this part of the country; in fact, it is about as much as the entire cost of the ordinary water works. I have just been in a town where the municipal supply is so salty that it can only be used for washing purposes, being unfit for domestic use or in boilers. The sale of bottled water in this town, a town with a population of 75,000, averages $9.00 per capita per year. That is, the bottled water people are taking $35.00 to $45.00 per family per year. These

people feel they are justified in voting as much as $90.00 per capita for a water supply alone, and have just voted the money by a majority of four to one.

J. J. WOLTMAN: Owing to the hardness of the municipal supply, practically all of the homes in Bloomington are equipped with cisterns and pneumatic water plants of different kinds each of which represented an investment of from $200 to $400. With a majority of the 6000 to 7000 homes here so equipped the amount so invested would be enough to provide the soft water supply for the city as stated by Mr. Howson.

L. R. HOWSON:[2] As I recall the Bloomington studies, it was not very hard to justify an expenditure of $1,000,000 to $1,250,000 when consideration was given to the questions of the cost of soap, the cost of duplicate plumbing fixtures, and similar items.

DETERMINING HYDROGEN ION CONCENTRATION FOR FILTER PLANT OPERATION[1]

By William D. Hatfield[2]

Applications of the determination of hydrogen ion concentration are coming more and more to the attention of the water works chemist, because the complete precipitation of aluminum hydroxide is dependent on the pH value of the treated water. The efficiency of coagulation, sedimentation and filtration is dependent on the character of the floc, and this appears to be controlled, to a large degree at least, by the pH value of the water. The pH determination is also of value in correcting the corrosive properties of treated waters.

Formulae for the calculation of pH values from the alkalinity and carbon dioxide content of the water have not given satisfactory results on the Lake St. Claire water. The calculation is much more tedious than the colorimetric determination. It is the purpose of this paper to give the author's experience in the application of some of the colorimetric methods to raw and treated waters in filter plant operation, covering a period of twelve months of routine work at the Highland Park, Michigan filtration plant.

Evans (1) has shown that the determination of the pH value with the hydrogen electrode on solutions containing a carbonate equilibrium is in considerable error unless special precautions and corrections are made. The problem therefore resolves itself into a study of colorimetric methods.

The buffer and indicator solutions recommended by Clark and Lubs (2) have proven satisfactory and have been used as standards against which all other methods should check. This method is recommended for all laboratories where there are trained chemists and calibrated apparatus. The color standards may be preserved for four weeks with three drops of toluene, if they are tightly stop-

[1] Presented before the Chemical and Bacteriological Section meeting, Philadelphia Convention, May 19, 1922.

[2] Laboratories of the Highland Park, Mich., Filtration Plant.

pered with paraffined corks and kept in a cool dark place when not in use. In using these semi-permanent standards the indicator solution must be kept under the same conditions as the standards, for the indicator solution may change.

Levy (3) recommends the use of two buffers, which were originally proposed by Sørenson for blood work, in which the range of pH is 6.4 to 8.4. For many filter plants these would be sufficient and are much easier to make than the Clark buffers. Indicator standards made with these buffers, three drops of toluene and stoppered as mentioned above are equally as good as the Clark standards.

Acree and Mellon (4) have developed a single buffer solution which with N/5 NaOH will cover the pH range for water work. This buffer solution may be purchased from the Pyroelectric Company. The solution which the author has gives buffer mixtures which read 0.1 lower than the Clark or Sørenson buffer mixtures.

Massink (5) recommends neutral red in preference to phenol red for dilute solutions as natural waters, claiming that the phenol red results are low because of the low salt content of the water. Comparisons in this laboratory show that neutral red gives results that are 0.3 pH higher than with brom thymol blue, phenol red, cresol red or m-nitrophenol. Kolthoff (6) proposes permanent mineral color standards for neutral red, but in this laboratory the weight of evidence is 4 to 1 against the use of neutral red for water work.

Colorimetric methods, using the Clark and Lubs indicators, but without the use of buffer solutions, have been proposed. Such methods, if accurate, are most applicable to the average water work laboratory. The color standards are made up of sets of two tubes each, one of acid solution and the other of alkaline solution. By varying the ratio of indicator in the acid and alkaline tubes it is possible to obtain any degree of color from the pure alkaline to the pure acid color. The pH value of any pair of tubes may be calculated from the formula $pH = K_i + \text{Log}_{10}$ (alk. form.)/(acid form.), if the indicator constant K_i is known. Great care must be taken that the proper strength of acid and alkali are used for a particular indicator or the true color will not be produced.

Medalia (7) suggested a method "without buffers," but with phenol red and cresol red the acid is too strong and the proper acid color of the indicators is not obtained. The pH values of the pairs of tubes are not calculated properly. The method gives standards

which are sometimes off-color as much as 0.3 pH, and therefore it cannot be recommended for water work.

Gillespie (8, 9) proposed a method based on the modern theory of indicators which is accurate and simple in technic. It requires about ten minutes to prepare a set of color standards according to this method, and only a few pipettes, test tubes of uniform diameter, distilled water, dilute acid and alkali. The standards prepared are so reliable that the author has used them to check up buffer solutions. The drawback to this method is that the standards are not permanent for more than a day.

Since color standards made with buffer solutions may be kept for a month by adding a few drops of toluene and stoppering, it occurred to the author to modify Gillespie's method by substituting roughly prepared solutions of buffer salts or acids for the production of the acid and alkaline colors instead of dilute acid and alkali. The rapid fading of the Gillespie standards is due to the change in pH of the solution because of CO_2 from the air or the action of the solution on the test tubes. Buffer solutions resist slight changes due to these causes.

Three drops of toluene added to the color standards is a handy preservative for all the indicators recommended by Clark except methyl red. In the acid tubes of methyl red toluene extracts the yellow or alkaline form of the indicator, thereby shifting the equilibrium and lowering the amount of acid color in the standards. If the buffer solutions are saturated with thymol before the standards are made up, the standards will keep well, though the shade of color is slightly different. With the exception of methyl red, all color standards prepared according to the method given below have been kept without change of shade for from four to eight weeks both in winter and in summer.

Modification of Gillespie's method

Indicator concentration. Use concentrations of indicators from 0.004 to 0.012 per cent as recommended by Gillespie (see table 1) wherever possible. The author finds, however, that different indicator powders will not give solutions of the same color intensity and that it is often necessary to double or even triple the above concentrations in order that good color differentiation be possible. On Lake St. Claire water, higher concentrations than triple that recommended give high results. The original concentrations recommended by Gillespie give the same final concentration of indicator as the "four drops per 10 ml" of the indicator solutions recommended by Clark.

Approximate buffer solutions. The following solutions are used to produce the acid and alkaline colors of the indicators instead of 5 ml of distilled water plus dilute acid or alkali, as in Gillespie's method. Table 1 indicates these solutions by the Roman numerals given below.

I. N/1 Acetic acid (57.7 ml glacial acetic acid per 1000 ml dist. water) for the acid colors of bromphenol blue, and methyl red.

II. 0.7 per cent KH_2PO_4 (C. P. Baker's Analyzed) in dist. water for the acid colors of bromcresol purple, bromthymol blue, phenol red, cresol red, and thymol blue (alkaline range).

III. 1.8 per cent Na_2HPO_4. x H_2O (C. P. Baker's Analyzed) in dist. water for the alkaline colors of bromphenol blue, and methyl red (also for B.C.P. and B.T.B. if desired).

IV. 0.1 per cent Na_2CO_3 (C.P.) in dist. water for the alkaline colors of bromcresol purple, bromthymol blue, phenol red, cresol red and thymol blue.

Table 1 gives complete data for making the indicator solutions and standards. It is essentially the same as Gillespie's table, except that Gillespie uses five ml of water in each tube (10 ml for the 3/17 and 17/3 ratio) and one drop of 0.2 per cent NaOH to form the alkaline color of all indicators; to form the acid colors: 1 ml 0.05 NHCl (1 ml con. HCl diluted to 240 ml with dist. water) and four ml dist. water for bromphenol blue; 1 drop 0.05 NHCL and 5 ml dist. water for methyl red, bromcresol purple, bromthymol blue, and phenol red; 1 drop 2 per cent KH_2PO_4 and 5 ml dist. water for cresol red and thymol blue.

A color comparator made after the plan in Bunker's article in his Journal, vol. 9, page 106, but 24″ x 3″ x 3″ with 23 sets of three holes instead of three sets, is most convenient. The standards are set up in alternate sets of holes and the comparisons are made without handling so many tubes. The indicator solutions should be kept in colored bottles which are stoppered with stoppers containing 1 ml pipettes. It is essential that the same pipette be used in making the drops for both standards and unknown solutions. Because of the weak buffer value of natural waters they should not be diluted with distilled water before the test, as is done with bacteriological media. In case of high turbidities the water may be filtered through filter paper and the test made after discarding the first 100 ml.

The determination is best made on a freshly collected sample, however, if a good glass stoppered bottle is completely filled and stoppered the pH value will remain constant for 24 hours or more. Temperature corrections are not necessary between one and twenty-five degrees Centigrade. The same samples of water at different temperatures between the above limits are so nearly the same

shade that corrections or warming of samples are unnecessary. The pH value of the treated water in Highland Park is the same at the end of the mixing chamber, in the influent and effluent of the filters and on the tap water which is chlorinated.

Michaelis (10) proposed a method "without buffers," using m-nitrophenol, a one-color indicator. The technic of this method is

TABLE 1

Data for the determination of pH values

DROPS OF INDICATOR IN		DROPS OF BUFFER TO EQUALIZE LEVEL IN TUBES		pH VALUES OF EACH PAIR OF TUBES						
Acid tube	Alkali tube	Acid	Alkali	Brom phenol blue	Methyl red	Brom cresol purple	Brom thymol blue	Phenol red	Cresol red	Thymol blue
1	9	9	1	3.1	4.05	5.3	6.15	6.75	7.15	7.85
*3	17	17	3	3.3	4.25	5.5	6.35	6.95	7.35	8.05
2	8	8	2	3.5	4.4	5.7	6.5	7.1	7.5	8.2
3	7	7	3	3.7	4.6	5.9	6.7	7.3	7.7	8.4
4	6	6	4	3.9	4.8	6.1	6.9	7.5	7.9	8.6
5	5	5	5	4.1	5.0	6.3	7.1	7.7	8.1	8.8
6	4	4	6	4.3	5.2	6.5	7.3	7.9	8.3	9.0
7	3	3	7	4.5	5.4	6.7	7.5	8.1	8.5	9.2
8	2	2	8	4.7	5.6	6.9	7.7	8.3	8.7	9.4
*17	3	3	17	4.8	5.75	7.0	7.85	8.45	8.85	9.55
9	1	1	9	5.0	5.95	7.2	8.05	8.65	9.05	9.75
Per cent indicator soln. used by Gillespie.....				0.008	0.008	0.012	0.008	0.004	0.008	0.008
ml 0.1 N NaOH per 0.1 gram indicator for stock soln....				1.64		2.78	1.77	3.10	2.88	2.38
Produce acid color with 5 ml (10 ml for 3–17 ratio) of Buffer No.....				I	I	II	II	II	II	II
Produce alkaline color with same amount of buffer number.....				III	III	IV	IV	IV	IV	IV

Eleven pairs of test tubes of uniform diameter are set in a comparator, the correct number of drops of indicator added to each tube, the correct number of drops of the proper buffer solution to total ten drops in each tube, then 5 ml of the buffer. Three drops of toluene in each tube (except for methyl red), and stopper with paraffined cork stoppers. *Note: the second and tenth pairs require 10 ml of buffer in each tube instead of five.

To 5 ml of the unknown add 10 drops of the right indicator and compare with the standards compensating for turbidity and color in a comparator.

different from that of Gillespie's, is not so convenient, and the color differentiation is poor. Fairly satisfactory results were obtained on clear colorless tap waters, but turbidity and color interfere, so that the method is practically useless on raw and treated waters in plant operation. The technic of the method is such that it is nearly impossible to compensate for color and turbidity.

SUMMARY

In large plants, with good laboratory facilities, the most accurate method for determining the pH value of the water is by the buffer indicator solutions of Clark and Lubs, but in the average plant the method of Gillespie or the modification suggested by the author is more advisable and equally as accurate if carefully done.

Color standards prepared with buffer solution may be preserved for from four to eight weeks with a few drops of toluene, if the tubes are stoppered with paraffined corks and are kept in a dark place.

A modification of Gillespie's method "without buffers" is proposed in which the standards are relatively permanent.

The method of Michaelis is not applicable to turbid and colored waters.

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PRESENT DAY TARS FOR PIPE COATING[1]

By W. R. Conard[2]

When we study pipe for carrying water we naturally ask the question, why do we put a coating on these pipes? We do not find it necessary in the case of wood, cement or terra cotta, but iron or steel corrode and contaminate the water, forming obstructions on the interior and thereby causing loss of volume and velocity of flow. The corrosion may so deteriorate the walls of the pipe that eventually there is failure of the structure. The outside of the pipe, particularly steel, is also subject to deterioration, depending somewhat on the character of the soil and other influences.

Because of their greater strength, both iron and steel have been more universally used for water carrying purposes than any other material and it is probable that they will continue to be the most extensively used for a long while to come.

When iron was first used for water pipe, I do not know what material if any was used to coat them, but more than 70 years ago a process for coating cast iron pipe using coal tar was developed by Doctor Angus Smith and this process or variations of it have been in practically constant use since for cast iron. This material or coatings with an asphaltum base have been used for wrought iron and steel. For the smaller sizes of wrought pipe galvanizing has also been extensively used, as well as lead and cement lining. At the time Doctor Smith developed his process "coal tar" was a residual of the manufacture of gas from coal, just as it is today, only in those days the many by-products to be obtained from this residue were apparently little known, and the tar was in every way what is termed "virgin tar." Could the good Doctor have foreseen some things, such as by-products, tar from oil and water gas sets, etc., it is probable that he would have given much more detailed specifications and placed many safeguards around the coating.

The standard specifications of today state:

[1] Presented before the Philadelphia Convention, May 18, 1922.

[2] Of Conard and Buzby, Burlington, N. J.

Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300 degrees Fahrenheit immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipe are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300 degrees Fahrenheit (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated the pipe shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

All of this follows somewhat the specifications as first developed by Smith, but you will immediately note the term "coal tar pitch varnish." Pitch and varnish are used a number of times when as a matter of fact the material is neither pitch nor varnish, as they are generally understood. Pitch is the residue of tar after distilling, or is an extract of "pine tar," and varnish is generally understood as being a resinous product. Besides the kind or kinds of oil and the proportions are not definitely stated. In this connection variations in season and weather, and the opinions of individuals, should be offset by definite statement.

Average coal tar is made up of carbons, oils, acids and gases. The acids and gases are in the form of hydrogen, oxygen, nitrogen, sulphur. Its main body is carbon and it is the carbon held together by the oils which protects the metal from corrosion. It is the acid that tends to attack and corrode. Therefore it is desirable to get for pipe coatings a tar as free from acids as possible, and as high in carbon and oils, especially the heavier oils, and to use the coating at temperatures that will not evaporate the oils.

Coal tar and the by-products extracted therefrom are put to a wide variety of uses. The heavier material usually called tar (no matter how much it has been distilled or refined) is used for paving, road work, the varying forms of roofing materials, such as paints, etc., while the lighter part is used in many lines of industry, particularly the chemical, so that its value is greater for refining

purposes than in its crude state, which condition is the best for pipe coating purposes. The result is that, unless the pipe maker controls some source of production, he has to compete with the refiner, with the consequence that there are times when he gets left, and the pipe purchaser is the innocent sufferer. This does not mean that the pipe maker is willing that this be so, but it is simply the result of circumstances.

It may prove to be several generations in the future before the supply of bituminous coal from which we get our tar is exhausted, but as the by-products become greater in variety and value, the keener the pipe maker will have to compete, and the greater will become the cost. At present the tar used for pipe coatings is about 15 per cent of the total cost of coating pipe, and my thought is, when is the point going to be reached when economy ceases, in using coal tar, and what other material or materials can take its place.

It is not the purpose of this paper to attempt to cover technically the subject of pipe coatings. It is the belief of the writer that, while the pipe maker specifies and tries to get "virgin tar," the tar does not contain as large a proportion of the heavy mineral oils as the tars of Doctor Angus Smith's time contained. There are cases, therefore, where the coating is not as durable as it was once. It is my further belief that it is time that careful and more extended studies were made to see what might be done about it. I consider it entirely within the range of possibility that, even using coal tars that have had their by-products extracted, together with some other material or materials, whether oils or some other form of binder, a better and more durable coating than the present may be found. I would not suggest discarding tar entirely, for as I view it there has not yet been found anything that could within economic limits take its place. I do not think, however, that the virgin tar of today is the last word in pipe coatings. Thorough research probably would develop some other material to use with tar that would form a much bettter protection for iron and steel pipe surfaces than we are now using.

When I speak of the need for research work, it should not be concluded that no investigation has been made. Mr. Dexter Brackett, in the eighteen nineties, made tests, keeping Mr. Thos. Wiggin at the foundries for many months to try and get a better coating. Mr. Allen Hazen in 1908–9 had some careful work done. Mr. Clarence Goldsmith, about 1913, for the Boston High Pressure Fire Service, in collaboration with Mr. Frank McInnes, tried a variety

of tar coatings. The results of Mr. Brackett's and Mr. Wiggin's work, in large measure, are the specifications as at present written. Mr. Goldsmith's work gave a specification using tar and rosin, which gave a coating of good appearance, but, due to the temperatures used, did not appear to have the lasting qualities required. The investigations of Mr. Hazen caused him to favor a tar distilled until the naptha was removed, with enough linseed oil to give a smooth tough and tenacious coating for steel pipe. As he applied this coating apparently primarily to steel pipe, and I do not see it mentioned for cast iron, it is assumed that the present standard requirements for cast iron are acquiesced in by Mr. Hazen.

Apparently all of these investigators looked up other materials, and by a process of elimination returned to coal tar. At the same time, all apparently agree that the factors of heat of the pipe for varying thicknesses, heat of the tar bath and the proportions of fresh and old tar are of prime importance. But the control of all of these factors requires men of greater skill and intelligence than the average pipe coater has. Better, and more extensive apparatus and facilities for doing the work than exist even at the present time are necessary.

From my observation of pipe, which has been in service and, for some reason, has been taken out, my conclusion is that the coating on the pipe is not impervious to moisture, but has small pores which usually extend through the coating. This allows the moisture to get to the metal, so that ferrous oxide forms and comes out through these pores and spreads over the interior of the pipe. Perhaps you may have noticed in pipe taken out that, when some of the scales formed are removed, apparently good coating is found underneath. While, as stated before, I do not see that tar should be discarded, research should be carried out to see whether there is something to use with the tar that will seal the pores, which will prevent the forming of the ferrous oxide and of tubercles.

Somewhat the same effect is obtained when pipe is allowed to remain in the open, except that in that case the ferrous oxide begins to form under the coating and causes the coating to scale off. I believe, too, that investigation should be made of the question as to whether pipe of different sizes and classes should be dipped in the tar bath at different temperatures, for the volume of the metal in the pipe controls the number of heat units to be thrown off before the coating may become set. As long as the heat prevents the setting of the coating, the heat will also continue to evaporate the oils in the tar and tend to leave nothing but dead pitch.

As to what materials might be used in conjunction with tar to prevent the forming of iron oxide, there are these thoughts that have occurred to me. One is to coat, especially the interior of the pipe, with some paraffin substance before applying the tar. This was suggested casually by Mr. S. B. Brown of Warren Foundry. The other is the use of some substance that has no oil or gas forming constituent, but is dense and, when set, impervious to moisture, which will become fluid at approximately the same temperature as tar, will mix with tar readily, may therefore be put in the tar tank and may be applied in conjunction with the tar. And still another might be to find some means of getting a much thicker coating on the pipe, which would adhere and not tend to scale in cold weather, and soften and run in hot weather. The City of Philadelphia had and I think still has a specification that the coating shall be at least 1/64 of an inch thick, which would help some. I do not think it is thick enough, but with the existing methods at the foundries and the tars used it is difficult of attainment.

If tars only are to be used, every known constituent should be determined and careful experiments made in an endeavor to learn which are beneficial and which harmful to pipe as a coating and which will give the longest efficient life.

In summary, it may be stated that apparently present day virgin tars do not appear to contain as great an amount of the heavy oils as the old tars, and probably have more of the lighter oils which evaporate more readily.

Present day specifications are at variance with the process developed by Doctor Smith, and the demands of the pipe purchasers of the manufacturer have been such that the old Smith Method, which was a rather lengthy operation and involved dipping the pipe cold in hot tar and allowing them to stay in the bath until the pipe became hot, could not be worked today unless much more elaborate apparatus than that of Doctor Smith's time were installed.

Research if undertaken should be along at least two lines, to indicate:

The apparatus necessary to care for the present day volume of production, going back to a strict adherence to the Doctor Angus Smith process or,

Using present apparatus and methods, or something similar in rate of working, some material to mix with the cheaper distilled tars to get a coating that will be as lasting and protective as the old Smith process, or else something better.

MICROBIOLOGY AND THEORY OF ACTIVATED SLUDGE[1]

A. M. BUSWELL[2] AND H. L. LONG[3]

PART I

INTRODUCTION

In reviewing the expressions of opinions with regard to the theory underlying the activated sludge process of sewage disposal one soon comes to the conclusion that two main lines of action are held responsible for the results obtained. That the mechanism of the reaction is sometimes described as that of adsorption of the colloidally dispersed matter by sludge already present in the sewage is evident from the following statement quoted from well known authorities (1).

"The sludge embodied in sewage and consisting of suspended organic solids, including those of a colloidal nature when agitated with air for a sufficient period, assumes a flocculent appearance very similar to small pieces of sponge. Aerobic and facultative aerobic bacteria gather in these flocculi in immense numbers, some having been strained from the sewage and others developed by natural growth." In other words, the usual suspended particles in sewage grow by the accretion of material colloidally dispersed, thus producing activated sludge.

Other writers refer to the "scrubbing action" of suspended particles, and compare the action of activated sludge to that of coagulated alum (2). The process is often referred to as one of oxidation, assuming that oxidation is a principal step in the purification of sewage. Another definition states that activated sludge must be of "a character to absorb colloidal matter," and another author refers to the (3) "clotting" of the colloids in the sewage. Such expressions seem to indicate what might be called a colloidal or mechanical theory for the mechanism of the action of activated sludge, similar in many respects to the Hampton Doctrine of the action

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of sewage filters. Ardern (5) summarizes the latter as follows: "According to this theory the purification process is primarily and essentially a de-solution effect brought about purely by physical causes and that any bacterial or biological action is definitely ancillary."

The other theory which one meets, and which in reality seems to have been the first to be proposed, is what might be called the biological theory and resembles Dunbar's theory of sewage filters. Those emphasizing this viewpoint of the action of activated sludge call attention to the analogy (4) between the action of slate beds, contact beds, and sprinkling filters and the action of activated sludge. The sludge is referred to by these writers, not as a clotted, agglomerated, or coagulated sludge produced by the mechanical growth of suspended particles in the sewage, but as biological growths arising from the germination and propagation of microörganisms whose "spores" are always present in sewage. The term "cultivated sludge" (6) used by one author, contrasts perhaps as strongly as any with the term "coagulated" or "agglomerated" sludge, used by those favoring the colloidal theory.

Of the authors who favor the biological theory, we find that some (7) refer to nitrification and nitrifying organisms as requisites for the success of this method of sewage treatment, while others refer to the sludge as being composed of a variety of microörganisms. Mumford's (8) M7 seems to have been the only specific organism mentioned as having ability to produce the purification of sewage. This organism, it will be remembered, required for its best activity appreciable amounts of iron.

If one examines particles of activated sludge under the microscope he is immediately impressed with the fact that there is practically no adsorbed, precipitated or coagulated amorphous matter in these sludge particles, but that they are composed entirely of active growing microscopic organisms of varieties ranging from true bacteria up through the giant bacteria, with occasionally molds and yeasts, and including as well, a variety of free swimming and attached protozoa (10). These communities of microörganisms must obtain food and this food must be supplied from the colloidal and dissolved matter and salts in the sewage. From what we know of the metabolism of microörganisms it is probable that the unicellular forms are absorbing through their membrane such soluble forms of organic matter as are able to pass through this membrane, and that they are also secreting enzymes which are capable of peptizing or

liquefying colloidal particles too large to be directly absorbed. Protozoa, on the other hand, can easily be seen to approach and ingest visible particles of organic matter. This biological theory of the action of activated sludge might be summarized and emphasized by proposing what seems to be a rather striking analogy, namely, that the purification of sewage effected by microscopic communities appearing as flocs is entirely similar to that of disposal of garbage by feeding it to hogs. It does not seem probable that adsorption of colloids or mechanical precipitation plays any greater part in the metabolism of microörganisms than they do in the digestion of the larger animals. One serious objection to the colloidal theory of coagulation is that the colloidal particles in sewage and the activated sludge particles are, so far as we are able to determine, both negatively charged. Since adsorption of colloids is most effective between oppositely charged particles it should not be applied to the conditions of the activated sludge particles without reservation. Furthermore adsorption is an almost instantaneous action while considerable time is required for the activated sludge reaction.

Discussion of the theory at this time may seem academic and impractical. Since, however, these two theories would suggest rather different lines of attack on the general problem we have chosen to review and compare them.

If the action is largely colloidal and mechanical, then we will need to study particularly the colloid chemistry of the sewage. If, on the other hand, it is biological, we will need to study the biology of the sludge, and should have for the sake of the success of the activated sludge process a most complete knowledge of the desirable and undesirable members of these microbial communities upon which we are to rely for the purification of sewage.

The biological theory suggests a somewhat different notion of the importance of oxidation in sewage purification than that ordinarily expressed. When garbage is disposed of by feeding to hogs only as much oxidation takes place as is required to furnish energy for the life processes of the hogs. Final oxidation does not take place until the pork chops are eaten and burned up in the body to furnish human energy. If the analogy of this process to sewage disposal is admitted, oxidation appears as an incidental reaction. Clark (9) in 1912 called attention to this viewpoint in the following manner: "In experiments upon aeration of sewage tried during the past twenty-five years by various investigators, as described by Drown, Dupre and Dibdin, Mason and Hine, Black and Phelps,

etc., the chief object of each study has been to learn the oxidation changes induced by such treatment. The collection of suspended and colloidal matters, as here described, is an entirely new feature of aeration work."

Comparatively little has been published on the organisms of activated sludge. Earlier writers make especial mention of nitrifying bacteria, Bartow (11) and Smith noticed large numbers of worms (Aeolosoma Hemprichii) as well as Vorticella and Rotifera at times in the sludge, Purdy (10) counted the various protozoa in strawboard waste activated in a 3-inch glass tube and fed by the fill and draw method.

More recently Dienert (12) and Cambier (13) have debated the rôle of bacteria in the activated sludge process. Dienert maintains that bacteria are essential, since nitrification did not take place in the presence of phenol. Cambier on the other hand maintains that the activated sludge process is an example of ordinary chemical catalysis. His conclusions appear to be based on three experiments: one in which chloroform was introduced with the air used for aeration, apparently on the assumption that the chloroform would be a germicide; one carried out at low temperature (0°–12°C.) on the assumption that nitrifying bacteria are not active at these temperatures; and one in which iron sulfide was added. That nitrification and purification were accomplished under these conditions Cambier interprets as proof of the catalystic theory of the reaction. He presents no definite data, however, to show sterility of his solutions. In the same journal Courmont (14) reports a study of the bacterial flora of activated sludge effluent. He found seven species, one of which was B. subtilis. No obligatory anaerobes were found and in some cases B. coli was absent.

Richards and Sawyer (15) have recently presented data including chemical analyses, bacteria counts and microscopic determinations of the number of protozoa. A relation was established between the number of protozoa and bacteria, and the high nitrogen in the activated sludge was attributed to synthetic living protein of the bodies of bacteria and protozoa. Under certain conditions of aeration free ammonia and nitrates were synthesized into proteins, as contrasted with the formation of free ammonia and nitrates which is ordinarily observed in the activated sludge processes.

Of the various investigations which have been made that of Purdy (10) furnishes the most complete data on the various organisms present in the sludge. Purdy followed the usual Sedgwick-

Rafter method for enumerating the microscopic organisms, reporting the zoogleal flocs in standard units of 0.004 mm. sq. Purdy used a 500 cc. aerating vessel operated with an unmeasured excess of air on the fill and draw system with 24-hour aeration periods. This system served admirably the purposes of the particular investigation which showed the presence of relatively large numbers of protozoa, especially of Peritrichs. Some work of the present authors on a similar scale and with excess of air and 24-hour fillings gave similar results. They do not seem to correspond to results obtained when smaller amounts of air are used, nor with the results on larger experimental units.

The analytical data herewith reported refers to samples taken from the aeration chambers of a two tank Dorr-Peck activated sludge unit fully described elsewhere (16). For the purpose of the present paper it will be sufficient to state that the apparatus was treating about 65,000 gallons per day in two aeration chambers having capacities of 14,400 and 12,700 gallons respectively and operated in series. Approximately 0.75 cubic feet of air was used per gallon of which two-thirds was used in the first tank and one-third in the second. A good degree of clarification and an average methylene blue stability of three days were obtained during the run.

EXPERIMENTAL

Microscopic observation made during the winter of 1920–1921 indicated some sort of a relation between the amount of air used, the strength of the sewage, the settling rate of the sludge and the types of organisms composing the sludge. When in the spring, after a shut down for repairs, the plant was started up without any activated sludge as a "starter" daily microscopic observations were made to follow the changes in microbial life as the sludge built up. The daily records, which on account of the unexpected pressure of other work had to be limited to brief observations, are given below. In general it is to be noted that the Holotrichs were the first to appear in noticeable numbers but that they gave way in time to other forms. The Peritrichs (Carchesium and Vorticella) appeared only after several days of aeration. The matured sludge seemed to be composed largely of zoogleal masses with frequent colonies of Peritrichs and an occasional Hypotrichs (generally Euplotes).

Summary of microscopic observations May 3–17, 1921

May 3 Plant started operation.

May 4 I. A few Paramecium, paper fibers and miscellaneous vegetable cells.

May 5 I. Paramecium, paper fibers and miscellaneous vegetable cells.
II. Gelatinous masses of fine bacterial filaments beginning to form.

May 6 I. Large flocs of gelatinous masses of fine bacterial filaments.
II. Zooglea, Paramecium, Colpidium.

May 7 I. Branching gelatinous masses of fine bacterial filaments, Paramecium, Spyrogyra.
II. Paper fibers with much attached zooglea. Many Paramecium, few Peritrichs (Vorticellidae), branched gelatinous masses of fine filaments.

May 8 I. Branched gelatinous masses of fine filaments, Paramecium, Colpidium, 1 filament of Spyrogyra.
II. Branched gelatinous masses of fine bacterial filaments few Holotrichs, mould hyphae and paper fibers.

May 9 I. First appearance of Peritrichs in I. One filament of Spyrogyra, gelatinous masses of filamentous bacteria.
II. Increase in Peritrichs.

May 10 I. Few ciliates, 80 per cent of field consists of gelatinous masses.
II. Many Peritrichs.

May 11 I. Largely gelatinous masses of filamentous bacteria; some Hypotrichs and Peritrichs.
II. Largely gelatinous masses of filamentous bacteria; fewer Peritrichs.

May 12 No change in character.
May 13 Increase in Peritrichs.
May 15, 16, 17 No changes in character.

In September the daily qualitative study of the sludge was resumed and a careful investigation of the forms in the zoogleal masses undertaken. In November an interruption in the operation of the plant offered another opportunity to study the forms appearing during the building up of sludge. In this series of examinations which dates from November 17, quantitative estimations were made, using the Sedgwick-Rafter method of enumeration as Purdy did. Beginning with the 9th of December, $FeSO_4$, equivalent to 10 mg. per liter of Fe was added to the influent sewage for the purpose of determining its effect on the nitrogen cycle. It appeared to be without effect on the character of the organisms found. The results of these examinations are given in the following table.

DATE	MINUTE CILIATES AND FLAGELLATES (THOUSANDS PER CC.)	PERITRICHIA (THOUSAND PER CC.)	HOLOTRICHIA AND HETEROTRICHIA (THOUSANDS PER CC.)	HYPOTRICHIA (THOUSAND PER CC.)	LARGER FLAGELLATES (THOUSANDS PER CC.)	NEMATODA (THOUSANDS PER CC.)	BEGGIATOA FILAMENTS (THOUSANDS PER CC.)	STANDARD UNITS ZOOGLOEA MASSES (MILLIONS PER CC.)	TOTAL SOLIDS Mg/l	PER CENT SOLIDS VOL. 1 HR. SED.
Tank I										
Nov. 17	2,885.0	0.10	0.30					0.11		
Nov. 18	215.0	0.30	1.40				0.20	0.38	2200	5
Nov. 19	90.0	0.60	1.90				0.30	0.37	2700	7
Nov. 20										7
Nov. 21	17.5	3.70	2.40			0.10	0.10	0.48	2930	8
Nov. 22	+	6.70	1.60			0.20	0.30	0.77	3370	9
Nov. 23	+	2.70	1.40			0.20	0.60	0.49	4030	11
Nov. 24										13
Nov. 25	+	8.60	3.60	1.20		0.10	0.30	1.08	4500	15
Nov. 26	+	14.07*	1.00	1.00		0.50	0.33	0.54	4900	18
Nov. 27										29
Nov. 28	+	6.50	3.00	3.80		0.70	0.40	0.10	5300	37
Nov. 29	+	12.85*	6.40	1.80		1.00	0.80	1.54	5800	48
Nov. 30	+	8.00	6.40	2.40		1.60	0.40	1.81	5430	68
Dec. 1	+	17.10	5.70	3.30		1.80	0.60	2.06	6140	76
Dec. 2	+	1.44	5.40	3.60		2.40	0.90	2.50	7350	78
Dec. 3	+	14.70	5.40	4.50		2.40	1.50	2.56	6480	84
Dec. 4										82
Dec. 5	+	4.00	0.60	0.80		1.00	0.40	1.11	6050	78
Dec. 6		3.00	4.80	2.70		3.30	1.20	1.70		
Dec. 7		5.00	2.00	2.50		1.50	2.00	1.51	5300	75
Dec. 8		6.50	2.00	2.00	5.00	1.50	1.00	2.40	4800	74
Dec. 9		4.00	2.50	1.00	55.00	1.50	4.00	1.71	4410	74
Dec. 10		6.80	1.60	1.60		2.00	1.20	1.24	4100	52
Dec. 11										64
Dec. 12	+	7.60	1.20	3.20	4.20	4.00	2.80	2.10	4270	56
Dec. 13		12.00	2.20	4.00			4.50	1.84	4260	57
Dec. 14		15.00*		2.00	10.00	1.00	3.00	1.56	3770	57
Dec. 15	+	13.00		3.00		0.50	5.00	1.99	4010	59
Dec. 16	+	5.00	1.00	0.50	5.00	1.00	5.50	1.55	3120	58
Dec. 17	+	1.60					0.80	0.82	3060	55
Dec. 18	−									60
Dec. 19	+	6.00		1.60		0.80	3.20	1.41	3180	54
Dec. 20	+	5.20	0.40	11.60			4.40	1.32	2910	56
Dec. 21	+	4.80		0.40			1.20	0.82	2660	62
Dec. 22	+	5.10		0.60			3.00	0.79	2450	54
Dec. 23	+	2.40	0.40	0.40			1.60	0.51	2640	54
Dec. 24	+	5.00	0.40	2.60			0.80	0.71	2800	67
Dec. 25										63
Dec. 26	+	17.00*	0.50	1.50			0.50	2.39	3650	70
Dec. 27	+	10.8	1.00	2.60		0.20	0.89	0.89	3820	61
Dec. 28	+	12.40*	0.60	1.80		0.40	0.40	1.10		81

DATE	MINUTE CILIATES AND FLAGELLATES (THOUSAND PER CC.)	PERITRICHIA (THOUSAND PER CC.)	HOLOTRICHIA AND HETEROTRICHIA (THOUSAND PER CC.)	HYPOTRICHIA (THOUSAND PER CC.)	LARGER FLAGELLATES (THOUSAND PER CC.)	NEMATODA (THOUSANDS PER CC.)	BEGGIATOA FILAMENTS (THOUSANDS PER CC.)	STANDARD UNITS ZOOGLOEA MASSES (MILLIONS PER CC.)	TOTAL SOLIDS Mg/l	PER CENT SOLIDS VOL. 1 HR. SED.
				Tank II						
Nov. 17										
Nov. 18	120.0		0.30			0.10		0.043	1370	1
Nov. 19	63.0	0.60	0.50				0.50	0.098	2360	2
Nov. 20										2
Nov. 21	75.0	1.50	0.70				0.20	0.224	1390	2
Nov. 22	12.5	2.90	0.80	0.10			0.30	0.132	1410	3
Nov. 23	+	1.10	0.40				0.20	0.231	1370	2
Nov. 24										3
Nov. 25	+	0.10	1.10			0.30	0.40	0.205	1120	2
Nov. 26		0.90	0.80	0.20		0.10	0.20	0.185	1220	2
Nov. 27										2
Nov. 28	+	1.20	0.50	0.20		0.10	0.10	0.145	1050	2
Nov. 29	+	0.50	1.00			0.10	0.10	0.055	900	1
Nov. 30	+	0.50	0.30	0.10		0.10	0.30	0.119	870	0
Dec. 1	+	0.60	0.10					0.024	890	
Dec. 2	+	0.10	0.40			0.10		0.026	780	
Dec. 3									790	
Dec. 4										
Dec. 5									1160	4
Dec. 6		5.10	0.60	0.90		0.90		0.725		27
Dec. 7		8.00	0.40	2.40		1.20	0.40	1.270	3970	60
Dec. 8		3.80	0.70	1.30		0.40	0.10	1.912	4570	64
Dec. 9		4.10	0.70	0.40		0.90	0.20	0.540	4610	62
Dec. 10	+	2.80	0.30	0.70		0.40	0.50	0.312	4780	74
Dec. 11										60
Dec. 12	+	13.20	0.40	2.40		2.40	2.40	2.010	4460	70
Dec. 13	+	16.00	7.50	5.50		3.00	2.50	3.400	4360	75
Dec. 14	+	16.50	0.50	2.50		2.50	3.50	2.012	4550	75
Dec. 15	+	9.50	0.50	5.00		2.50	1.50	1.987	3990	69
Dec. 16	+	9.00				1.50	3.00	1.712	4030	75
Dec. 17	+	7.60	0.40	0.40		0.80	1.60	1.500	3450	82
Dec. 18				*		*				82
Dec. 19	+	6.00	0.80	5.60		0.40	1.20	1.170	3610	86
Dec. 20	+	12.4	0.40	2.00			4.40	2.530	3610	88
Dec. 21	+	12.40		3.60		0.40	2.80	2.340	3530	92
Dec. 22	+	15.00	0.90	1.20		0.90	3.90	1.192	3270	83
Dec. 23	+	10.40		0.80			2.60	0.840	3000	92
Dec. 24	+	4.80		0.40			2.00	0.675	2690	89
Dec. 25										99
Dec. 26	+	3.80	2.20	2.00		0.20	0.20	1.025	3570	90
Dec. 27	+	4.80	1.80	2.40			0.20	1.170	3570	88
Dec. 28	+	6.40	0.80	0.80			0.20	1.405		87

* Colony or cluster of peritrichs present.

+, The standard unit is used here as a measure of surface only and = 0.004 mm. sq.

DISCUSSION OF DATA

In the study of the microbiology of activated sludge in its development from raw sewage there seems to be a definite succession or addition of forms, as the sludge develops. Beginning with the characteristic microörganisms of raw sewage as it is taken into the aeration chamber, there is a predominance of the minute flagellates and ciliates, with occasional Peritrichs and Holotrichs. In a few days the minute forms diminish in number until they become a negligible quantity while Peritrichs, Holotrichs, and Heterotrichs increase in number, the Peritrichs predominating throughout. As the minute forms become insignificant the gelatinous masses of the Chlamydobacteriacae and Nematodes appear, to be followed in a few days by the sudden appearance of Peritrichs. This point then brings us to the characteristic fauna and flora of the matured activated sludge, under the particular conditions of operation employed. Observations on the occurrence of the various group of organisms have been summarized as follows:

Minute ciliates and flagellates

The fauna of the samples taken November 17, two days after the beginning with raw sewage, was characteristic of the crude sewage. The minute ciliates and flagellates constituted practically the entire of animal life. These forms continued to predominate in decreasing numbers until the 7th to 8th days, when, with the gradual formation of the sludge there was a marked decrease, with a predominance of larger forms. From November 22 on, through the period of observation, minute forms were present, but not in sufficient abundance to enumerate. Perhaps there were more of such forms present throughout the period, but were hidden from observation by the heavy sludge. Of the typical forms present, the minute free-swimming individuals predominated, while the spherical "rolling" colonies of Synura were abundant.

INFUSORIA

Peritrichs

As indicated in the table the Peritrichs were the most abundant forms throughout the entire period of observation. Beginning with

a very low count they reached the point of predominance in eight days, with a count of 14,000 in eleven days, and continued to be the predominating type.

In many cases extremely high count was due to colonial forms being present or to clusters of individuals not colonial.

From December 5 to 16, the Peritrichs were more or less quiescent or encysted. From the 5th to 10th only a very few individuals showed signs of activity; other individuals were largely either quiescent or encysted. From the 12th to 16th quiescent and active individuals were in about equal prominence.

The predominating type of Peritrichs were Vorticella. Individuals of the Pyxidium type were quite common on November 29, December 5, 8, and 13, and occasional individuals were recorded at other times.

Occasional colonies of Carchesium were observed. While not observed at any time in the unstained sludge, a stalk of Zoethamnium, with its characteristic continuous muscle, was found on a prepared slide stained with fuchsin.

Colonies and individuals were invariably attached, by means of the more or less long stalk to the amorphous particles of the sludge. The occasional free-swimming stalkless individuals resulting from division were observed.

Hypotricha

After ten days of operation hypotrichs of the Euplotes type suddenly became abundant. No hypotrichs had been observed up to November 23. The 24th being Sunday no observation was made. On the 25th the calculated count was 1200 cubic centimeters. The count remained in the thousands the remainder of the period, reaching the highest count of 4500 on December 3 and next highest on the 31st.

In habits the characteristic Euplotes type was generally associated with the zoogleal masses of sludge where it apparently found its best forage.

The Holotrichia and Heterotrichia

Organisms of this class, principally Frontonia, were observed in the first sample taken, but in very limited numbers. With the evolution of the sludge they increased to a count of 6400 after

fifteen days but showed a marked decrease from this point on, with a total absence in many observations.

There is a similar curve in the unit mass content of the sludge but the drop is not as sharp as in the case of the Holo and Heterotrichous forms.

Suctoria

Suctoria of two types were observed. Individuals of the type Genus Podophyra occurred very rarely, while individuals of the type, Genus Acineta were quite common. One or two were observed in the field on the following days, November 20, 21, 23, 24, 25 and December 1, 3, 5, 6, 19, 21 and 28.

THE WHEEL ANIMALCULES

Rotatoria

The rotifers were so rarely observed during the forty-six days that they hardly deserve mention. Because of the concentration of the sludge from the beginning of formation to the climax apparently the conditions were not suitable for the life and multiplication of the Rotifers. However, in the small scale experiment carried on in laboratory and at the plant with large amounts of air, Rotifers became more abundant as the sludge became heavier and more concentrated.

In the small scale sludge experiment a much heavier sludge developed because only the effluent was removed. This condition seemed to be favorable to the Rotifers.

Individuals of the type, Genus Brachionus were observed but the forms most common were representative of the Genus Notommata.

ROUND WORMS

Nematoda

The Nematodes were of common occurrence in the experimental sludge after eleven days of operation. In the observations made on the large plant Nematodes were observed on the fourth day and gradually increased to 2400 per cc. on the 18th day, to a maximum of 3300 on the 21st day and then a gradual decrease that was comparable to the decrease in the Rotifers.

ZOOGLEAL MASSES

Having briefly reviewed the fauna of the sludge, we should turn our attention to the sludge proper. On November 17, after two days operation with raw sewage, units of zoogleal mass numbered 115,000 (see table); by November 25, 1,089,500; by December 1st, 2,062,500. The count continued ranging between one and two million units throughout the period, a count typical of a climax sludge maintained at the given dilution.

The animal inclusions of the sludge made up a very small part of the entire mass. The base of the sludge was composed of zoogleal masses intermixed largely with filamentous bacteria and occasional Zooglea ramigera.

It appears that the filamentous forms overwhelmingly predominate the sludge. The literature on filamentous forms is scattered and rather uncertain taxonomically. Therefore a more extended study of these inclusions and the literature is being made which will determine the species of the forms present. Crenothrix polyspora, Sphaerotilus dichotomus and Zooglea ramigera were undoubtedly present, however, in large numbers.

BACTERIAL SURFACE

Hering (17) long ago pointed out the importance of bacterial surface in sewage purification, though few definite data have been developed since his paper on the subject. From the table we may obtain a notion of the order of magnitude at least of the sludge surface in the activated sludge process. Take a case where two million standard units of zoogleal masses were found per cubic centimeter in the aeration chamber. Each floc must have a lower surface equal at least to the upper surface so that leaving out the side surfaces we would have four million standard units of 0.0004 mm. sq. each or 16 cm. sq. of surface per cubic centimeter of volumes. This figure does not include the surface of the protozoa or the free-swimming bacteria. If increased by fifty or one hundred per cent it would probably approach more closely the correct value. This would mean a surface of approximately 500 sq. ft. of sludge surface in 1 cu. ft. of the aeration chamber.

SUMMARY

In view of previous work of other authors cited and the data of the present paper we wish to propose the following statement of the theory of the activated sludge process. Activated sludge flocs are composed of a *synthetic* gelatinous matrix similar to that of Nostoc, or Merismopedia, in which filamentous and unicellular bacteria are inbedded and on which various protozoa and some metazoa crawl and feed. The purification is accomplished by ingestion and assimilation by organisms of the organic matter in the sewage and its resynthesis into the living material of the flocs. This process changes organic matter from colloidal and dissolved states of dispersion to a state in which it will settle out.

A calculation from data given indicates approximately 500 sq. ft. of sludge surface per cubic foot of aeration tank volume.

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WATER SUPPLIES FROM IRON MINES IN THE LAKE SUPERIOR DISTRICT[1]

By Ole Forsberg[2]

The data from which the following observations were made have been collected during the past year in the course of the examination of supplies furnishing water to the employees of the Oliver Iron Mining Company in the states of Minnesota and Michigan. The object and purpose of this work was identical with that of the Sanitary Division of the State Board of Health; namely, to assure that the Company employees are provided with water free from any injurious contamination. I do not expect to be able to present anything new or original, but some of the conditions met with in the mines and the problems dealt with may be of interest to those connected with the production of public water supplies.

In the development of a mine the removal and control of the water encountered is an important factor which necessitates the installation and maintenance of elaborate pumping equipment. The water taken care of comes from all parts of the mine, flowing along the bottom of the drifts or in launders into the dirty water sump. As it is not practical, or even possible, to protect this against pollution another supply must be obtained for drinking purposes. To do this it is often necessary to drive a special drift or even dig a well underground. Commonly, however, a drill-hole encountered in the progress of mining, or a worked out drift dammed off and converted into an underground storage reservoir, is used as the source. In all these cases every precaution is taken to prevent exterior pollution from entering the supply and to keep the mine water separate from the clear water. This requires the installation of a separate system so arranged that only when the mine is flooded can dirty water overflow into the clear water.

A typical example of a supply of this kind is that of the Village of Taconite, near Coleraine, where the water is taken from the Holman

[1] Presented before the Minnesota Section meeting, November 4, 1922.

[2] Bacteriologist, Hibbing Water Laboratory, Oliver Iron Mining Co., Hibbing, Minn.

Mine. The source of this supply is two drifts on the 200 foot level. A dam three feet high has been built across the mouth of each drift converting both into underground reservoirs. One drift is midway between the shaft and pump station running east 300 feet; the other is at the pump station running west 300 feet. Two 6 inch pipes conduct the water from the drifts to the centrifugal pumps which lift it into a 35,000 gallon elevated wood tank on the surface. The overflow from the drifts drains into the mine sump. A fire caused a stoppage of the mine pumps this spring and the entire mine was flooded for about a month, during which time the clear water supply could not be used. This illustrates the interdependence of one supply upon the other and one of the problems dealt with. Another supply of this type, yet somewhat different, is that of the Monroe Location near Chisholm. This comes from two distinct sources, a drill-hole in a drift on the 225 foot level, and a dammed-off drift on the 270 foot level of the Monroe Mine. The water from these two sources flows into the clear water sump at the main pump station from which it is pumped into an elevated tank on the surface.

The mine water from the Monroe Mine is also used as a source of water supply for the Village of Chisholm, being filtered and chlorinated before entering the distribution system. This supply was described by Mr. Sullivan in a paper presented before this section several years ago. The use of mine water as a source for a public supply is not common and I know of no other village or city in the Lake Superior region where this is done.

The impression must not be gotten that all mines are provided with separate supplies for furnishing water to the locations built up around them. Generally, as these locations or communities incorporate, they install a public supply which in time replaces that from the mine. Also, as not all mines find it practical to maintain a clear water supply of their own, water from the surface is sometimes piped or carried underground for drinking purposes. This is not often necessary because there is generally enough water flowing from fissures in the rock and ore body to supply the miners. In the Chapin Mine at Iron Mountain, Mich., and the Wanless Mine at Buhl, Minn., a steady flow of water in the nature of an underground stream has been encountered and is used as the source for the clear water supplies. In other mines drill or exploration holes produce a continuous flow; some even under considerable pressure such as at the Aragon Mine, Norway, Mich., where the

water from a drill hole is under pressure of over 100 pounds. Water for drinking purposes is generally available in the mines, though, as stated before, there are exceptions.

Mine water, coming from underground sources, is generally free from injurious contamination, and unless subjected to pollution during the process of delivery, is usually of good sanitary quality. The entire problem, from a sanitary point of view, resolves itself into keeping the mine and waste water from entering the clear water supply.

The chemical composition varies considerably and any classification along this line is practically impossible.

The hardness of all underground waters of this region is moderately high, while the alkalinity is due to bicarbonates. The mineral content is not excessive but some iron and manganese is usually present.

Where water is stored underground in contact with mine timbers, the decay resulting therefrom liberates more or less carbon dioxide which is absorbed by the water. This weak solution acts upon the ore dissolving some of the iron and manganese forming bicarbonates; a form in which these elements are readily retained in solution. Waters containing an excessive amount of either of these elements are objectionable for most purposes and necessitate treatment for their removal. This is being done by the Village of Franklin near Virginia, Minn.

Quite often timbering in the drifts gives way and caving occurs. This roils the water making it unfit for use until again cleared by settling. Last winter this was a common occurrence at the Penobscot shaft in Hibbing, the water carrying so much iron ore that packing in the pumps became impregnated with it and caused grooves to be worn in the piston rods.

In conclusion it may be said that water supplies of the iron ore mines of the Lake Superior region, which are obtained from underground sources, are of a good sanitary quality and the problem is to keep the water from becoming contaminated in the process of delivery. The mineral content is not excessive, and except in special cases, is not objectionable.

SOCIETY AFFAIRS

CENTRAL STATES SECTION

The annual meeting of the Central States Section was held in Pittsburgh on November 2 and 3, 1922. Following the registration of members and guests there was an address by the president, after which there were reports by the secretary, treasurer and trustees. These were followed by a résumé of the Melcroft Coal Company Case, by Dr. F. Herbert Snow.

The topics below were presented.

Water Power and Flood Problems as Related to Water Supply, discussed in its general aspects by J. N. Chester, with reference to Pittsburgh, by Morris Knowles, in Relation to Clarion River, by Chas. B. Hawley, and the Miami Conservancy Project by Chas. H. Paul.

Progress, Present Conditions and Aspiration of State Health Bodies, discussed by L. A. Geupel, F. C. Dugan, W. H. Dittoe, C. A. Emerson, Jr. and E. S. Tisdale.

The Operators' Attitude Toward Health Bodies' Activities, discussed by Clarence Bahlman, R. D. Bates, J. W. Ellms, C. P. Hoover, Theo A. Leisen, J. S. Dunwoody, W. H. Lovejoy, E. C. Trax, Dow R. Gwinn and R. W. Furman.

The following papers were then presented and discussed:

Incentive for Efficiency, by E. E. Bankson.

Description of Pittsburgh Water Works, by E. E. Lanpher, F. W. Lyon and C. F. Drake.

Stream Pollution Investigations by United States Public Health Service, by J. K. Hoskins.

Trips were made to the industrial plants in the Pittsburgh District, by those remaining over November 4.

MINNESOTA SECTION

The twelfth annual meeting of the Minnesota Section was held at Saint Paul, on October 27, 1922.

The opening address by the Chairman, J. W. Kelsey, was followed by the business session, after which the following papers were presented:

Experiences with Anaerobes at Minneapolis, by Frank Raab.

Advantages and Disadvantages of Elevated Concrete Tanks for Water Storage in Minnesota, by Arthur S. Milinowski.

The Removal of Iron from Spring Water, by John K. West.

Sanitary Supervision of Water Supplies in Iowa, by H. V. Pedersen.

Through the courtesy of J. W. Kelsey an excursion was made to the Saint Paul filtration plant, where luncheon was served.

In the afternoon a joint session of the League of Minnesota Municipalities and the Section was addressed by Perry Williams on the Sanitation of Tourist Camps and Resorts. A discussion by members of the Section was followed by these papers:

Water Supply, by Arthur F. Mellen.

Sewage and Garbage Disposal, by J. A. Childs.

Working Program, by H. A. Whittaker.

The organization cooperating in the program presented the following for discussion:

The Safeguarding of Municipal Milk Supplies, by Dr. R. W. Archibald.

Minnesota's Tuberculosis Sanitorium Program, by Dr. Robinson Bosworth.

Occupational Therapy in State Institutions, by R. W. Wheelock.

NEW YORK SECTION

On September 30, 1922, the New York Section were guests of the Consolidated Water Company of Utica. A paper on the biology of water works was presented by Professor Hodges. The meeting was attended by 130 members and guests.

On December 6, 1922, a meeting was held in New York. Luncheon was served at the Palais des Beaux Arts. Moving pictures of the old and new method of casting pipe were shown, by courtesy of the publicity department of the United States Cast Iron Pipe and Foundry Company, and were explained by John D. Capron, publicity manager. This meeting, with an attendance of about 90, was highly successful.

RESEARCH ON THE CORROSION OF STEEL PIPE

The National Tube Company, of Pittsburgh, Penna., has announced the establishment of an Industrial Fellowship in the Mellon Institute of Industrial Research of the University of Pittsburgh, Pittsburgh, Penna.

This Industrial Fellowship is engaged in a systematic study of practical methods for the prevention of corrosion in hot-water supply systems. It is also giving attention to the classification of waters of various chemical compositions, with respect to their relative corrosive action upon iron and steel, particularly in the form of pipe lines, boiler-economizers, tubes, etc.

The present incumbent of the Industrial Fellowship is Mr. Clifford R. Texter, who for the past several years has been carrying out research on the corrosion of iron and steel, where not exposed directly to the atmosphere. Mr. Texter will be glad to correspond with engineers and manufacturers interested in the field to which his Industrial Fellowship relates.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Pollution of Streams by Pulp-Mill Waste. GEORGE C. WHIPPLE. Proc. A.S.C.E., **48:** 6, 1385, August, 1922. Pulp mills pollute streams or canals with the spent chemicals from one of three processes ((1) Grinding; (2) Soda, and (3) Sulphite) for extracting the fibrous material, the third being the most serious. Prevention is worthy of study. European mills have closed because impossible to purify liquors sufficiently. Deposits become centers of microscopic life. This foul debris may drive away or kill fish, may injure water for boiler use, interfere with coagulation of water, requiring large quantity of alum and eight days coagulation at Watertown. Pulp-mill taste, corrosive qualities, and serious bacterial count, may remain in pulp waste polluted waters.—*E. E. Bankson.*

Wastes from Pulp and Paper Mills, Chemically Considered. H. W. CLARK. Proc. A.S.C.E., **48:** 6, 1393, August, 1922. About 10 per cent of soda process digester liquor is wasted. This liquor is 100 times as deleterious to a stream as domestic sewage, is deadly to bacterial life and to fish. One hundred per cent of digester liquor from sulphite process is wasted, but is slightly less deadly to bacteria and to fish. No reason why treatment should not be required, because products recovered would pay at least for the cost of treatment.—*E. E. Bankson.*

Experiments with Models of the Gilboa Dam and Spillway. R. W. GAUSMANN and C. M. MADDEN. Proc. A.S.C.E., **48:** 7, 1503, September, 1922. Presents the results of experiments made with models to determine the carrying capacity of a projected spillway channel and a satisfactory section of a stepped, overfall dam. There is also a discussion of the application of the principles of homology to the models in question.—*E. E. Bankson.*

Engineering Geology of the Catskill Water Supply. CHARLES P. BERKEY AND JAMES F. SANBORN. Proc. A.S.C.E., **48:** 7, 1529, September, 1922. The development of the Catskill Water supply system has been influenced by geological factors to a greater extent than is usual in most engineering enterprises. This paper shows how engineering problems were solved through the correct use of geological information. The choice of location, design of structures and details of construction were greatly influenced by the form,

relief, and underground conditions of the country traversed. Seldom in a large public enterprise of this kind, has so much trouble been taken to discover and to work out the important relations of topographic form and underground structure, and to apply the results of these studies to the problems of location, design, construction and operation of the completed system.—*E. E. Bankson.*

Motorized Laboratory for Resort Sanitation Work. W. C. Brockway and George C. Stucky. Eng. News-Record, **89**: 430–2, 1922. A motorized laboratory equipped for chemical and bacteriological analyses of water and foods is used by the State Dept. of Health of Mich. to protect pleasure seekers at summer resorts. Sanitary engineers accompany the laboratory to make sanitary surveys, distribute pamphlets and educate the public. About $5000 annually is spent in this way to protect the $100,000,000 summer resort business.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Pollution of Water from Deep Well. C. M. Baker. Eng. News-Record, **89**: 430, 1922. Contamination could enter the well at two leaks found in well casing where the booster pump is connected to the casing. The exhaust from the booster had been connected to the storm sewer. Expts. proved that, when air lifts were shut off, water siphoned into the drum of the booster through the exhaust. This demonstrated the possibility of serious contamination of the well.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Alternate Lime and Iron with Alum to Reduce Sand Size. R. W. Furman. Eng. News-Record, **89**: 530, 1922. Cementing and incrustant deposits on the sand grains lowered the efficiency of the filters by 39 per cent with lime and iron treatment. The use of alum removed a portion of the coating and rendered the remaining incrustation semi-porous. Hardness was slightly increased by use of alum for this purpose.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Unique Water-Works for Nabaclis, British Guiana. E. P. Minett. Eng. News-Record, **89**: 281, 1922. The water is pumped from a 600 ft. deep well. It contains 5.6 p.p.m. Fe which on aeration and filtration is reduced to zero. To avoid pitting of the iron pipes, the whole of the 6 inch mains were lined with bitumen. The sand filters are cleaned by reversing the flow about every 3 months.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Water-Works and Filtration Plant for Darien, Manchuria. Dr. Kuratsuka. Eng. News-Record, **89**: 244–5, 1922. The population of Darien is 187,000 and per capita consumption is 34 gal. daily for whites and Japanese, and 7.5 gal. for Chinese. Water is obtained from the Wangchiatien reservoir 11½ miles from town. Rapid sand filtration plant with 3.6 m.g.d. capacity was installed with provision for chlorination should it be required. This is the first rapid-sand filter plant in the Far East.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Excess Dose, Thickeners and Carbonation at Water Treatment Plant. Charles P. Hoover and Arthur R. Holbrook. Eng. News-Record, **89**: 342–3, 1922. At the new water softening plant under construction at Newark,

O., designed to treat 6 mil. gal. day., it is proposed to treat 25 per cent of the water with an overdose of lime, soda, and alum in a tank with 5 min. detention with violent agitation. This 25 per cent will then be mixed with the remaining 75 per cent and mixed in a baffled tank. After mixing the water is passed through a Dorr thickener with a detention of 22 min. The water is then settled for 8 hr. and carbonated by passing CO_2 and air through it. Expts. will be carried on of returning some of the sludge from the Dorr thickener to the raw water.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Water Purification Sweeps On. EDIT. Eng. News-Record, **89**: 173, 1922. It is pointed out that cities on the Mississippi and Missouri rivers and the Great Lakes not provided with water purification plants are taking steps to this end with the exception of Chicago. Mud and color rather than typhoid have spurred the cities to build the plants.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

New Water Purification Plant for Topeka, Kansas. BLACK AND VEATCH. Eng. News-Record, **89**: 153–5, 1922. This plant, recently put in operation, consists of 8 steps in the treatment, namely: aeration, grit chamber, settling basins, roughing and final filters, lime, alum and chlorine. Water is taken from the Kaw River ranging from 120 to 580 p.p.m. hardness and turbidity from 13 to 3385 p.p.m. Plant was designed to filter and serve 52,000 people. A description of the various units is detailed.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Prechlorination-Alum Treatment of Soft, Colored Water. ARTHUR L. GAMMAGE. Eng. News-Record, **89**: 391–2, 1922. Expts. and working results show that low colored mechanical filter effluent which is nearly non-corrosive can be obtained. The conclusions reached are, that low alkalinity and comparatively high CO_2 give better color removal than simply a final alkalinity of 10 or more p.p.m., as generally used in coagulated waters. Prechlorination lowers the color with the same amount of alum, or saves alum to obtain the same resulting color. Cl with alum gives better color removal with higher alkalinity and lower CO_2. Soft corrosive water may be treated with lime or soda after mechanical filtration rather than with coagulation in a treating basin before filtration, to secure much better removal of color and equal removal of CO_2 to obtain the lowest practical corrosive action with the purified water.—*Frank Bachmann.* (*Courtesy Chem. Absts.*)

Behavior of Lubricating Oil in Steam Turbines. W. F. OSBORNE. Power, **56**: 94, July 18, 1922. A discussion of the selection of the proper oil, the effect of the addition of moisture, and the general operation of a turbine oiling system. Illus.—*Geo. C. Bunker.*

A Common Error in Weighing Water. Power, **56**: 88, July 18, 1922. In testing boilers, pumps and other power-plant apparatus, it is frequently necessary to measure water by weighing it in a tank set on platform scales. In such cases care should be taken that the pipe supplying water to the tank

does not project below the surface of the water, because that will result in erroneous readings. Illus.—*Geo. C. Bunker.*

Diesel Engine for Small Plants. Power, **56**: 163, August 1, 1922. A discussion of motives prompting the Nordberg Mfg. Co. to design a Diesel engine of small power and a description of the important details of the design. Illus. —*Geo. C. Bunker.*

Lubricating Requirements of Steam Cylinders. W. F. OSBORNE. Power, **56**: 173, August 1, 1922. Cylinder friction is a very large proportion of the total friction losses of an engine and sometimes eats up as much as 10 per cent of the coal pile. A discussion of the conditions under which the cylinder walls are effectively lubricated.—*Geo. C. Bunker.*

Methods for Testing Petroleum Products. Bureau of Mines Technical Paper No. 298. Methods adopted by the Interdepartmental Petroleum Specifications Committee. Written as a handbook for testing laboratories in connection with the Specifications for Petroleum Products adopted by the same Committee. Well arranged and illustrated. 57 pages.—*Geo. C. Bunker.*

Proper Care of Boilers Prevents Water Going into Steam Lines. W. E. THOMPSON. Electrical World, **79**: 1224, June 17, 1922. A letter calling attention to circumstances under which water in a boiler will go over into the steam line and to the damages which will result. Attention is called to the liability of priming if the salt concentration runs much over 200 grains per gallon. (It is probable that some sort of a concentration meter will come into more common use in boiler rooms in order to determine the proper time for blowing-off a boiler. G. C. B.)—*Geo. C. Bunker.*

How to Make Forms for Concrete Buildings. W. F. LOCKHARDT. Concrete, **20**: 191, May, 1922; Beams and Girders; **20**: 239, June, 1922, Flat Slabs; **21**: 14, July, 1922, Flat Slabs, continued.—*Geo. C. Bunker.*

Controlling Quality of 400,000 Cu. Yds. of Concrete. RODERICK B. YOUNG. Concrete, **21**: 3, July, 1922. The control of the strength and quality of the concrete used during the construction of the Queenston-Chippewa development of the Hydro-Electric Power Commission of Ontario. Thousands of barrels of cement were saved and the cost of concrete proportionately reduced by methods which set up a definite field control of the mix, with a view to obtaining specified strengths of concrete at 28 days.—*Geo. C. Bunker.*

Fire Service from Water Works Standpoint. DOW R. GWINN. Fire and Water Eng., **71**: 563, April 5, 1922. Methods used in the care of fire hydrants and gate valves are fully described. Special emphasis is laid on the advantages arising from the adoption of the automobile pumper by the fire department in relieving the water works from the necessity of raising the pressure each time a fire occurs and in consequence subjecting the distribution system to an unnecessary strain which may at any time result in a bad break. 3750 words.—*Geo. C. Bunker.*

Determining Water Pressures and Fire Flows. WALDO S. COULTER. Fire and Water Eng., 71: 643, April 19, 1922. A summary of some of the data relating to hydrant pressures and fire flow tests which were collected during an Underwriters survey of the water works systems of New Jersey. 1850 words.—*Geo. C. Bunker.*

Malleable Iron Covers for Street Valve Vaults. DOW R. GWINN. Fire and Water Eng., 71: 645, April 19, 1922. Malleable cast iron covers possess greater tensile strength than those made from ordinary or grey iron and will withstand shocks from heavily loaded trucks without breaking. The action of the weather is slight. Illustrated. 1750 words.—*Geo. C. Bunker.*

Reducing Water Waste by Use of Meters. E. J. JENKINS. Fire and Water Eng., 71: April 26, 1922. An experiment successfully carried out by the East Chicago & Indiana Harbor, Ind., Water Co. Opposition of consumers was overcome through courtesy and showing of results in saving of expense to them. 1100 words.—*Geo. C. Bunker.*

Pollution from Private Fire Services. THORNDIKE SAVILLE. Fire and Water Eng., 71: April 26, 1922. A compilation of current views on this subject, with the following conclusions: (1) The use of polluted water for an auxiliary fire supply should be discouraged under all conditions. It should be permitted only under careful interlocking regulations of the state insurance commission and the state board of health. (2) Where an independent supply is used for private fire protection, the fire service connection from the public mains should discharge either into a cistern or elevated tank at or above the flow line, and the protected property be required to take all water for fire protection from the cistern or tank so as to prevent possibility of back flow into the public mains. (3) Where auxiliary fire supply is taken from a polluted source, any physical connection with the public water supply is disapproved. In the case of cities having a first or second class rating under the Underwriters' scoring of fire protection facilities, any physical connection with the public supply is prohibited. In other cases, physical connection may be permitted only by special regulation of the state board of health. In all such cases, the public water supply should be protected by a Factory Mutual Double Check Valve, with auxiliary devices for testing and giving alarm when leaking. Weekly inspection of these check valves and their proper maintenance should be required. (4) Where interconnection between the public water supply and an auxiliary fire supply is permitted, absolutely no use of the auxiliary supply should be made except for purposes of fire protection. (5) Water for domestic and manufacturing uses should be taken from the public main through a branch entirely separate and distinct from the branch serving the fire connection. Illustrated. 5200 words.—*Geo. C. Bunker.*

Practical Results in Reduction of Water Waste. L. A. SMITH. Fire and Water Eng., 71: 725, May 3, 1922. Water works system in Madison, Wis. is 100 per cent metered. All 2-inch and larger meters are read monthly, the smaller sizes are read eight times per year. Practically all meters in service

longer than five years have been tested and repaired. A considerable number of meters were found registering only 60 to 75 per cent of the water passing through them. Underground leaks were detected by aquaphones and bare spots when snow was on the ground. After three years the unaccounted for water was reduced from 23 to 17 per cent. A Pitometer survey was then made and a total water waste of 437,500 gallons per 24 hours or over 10 per cent of the total pumpage was found. The total cost of the survey, exclusive of repair work on services and meters, amounted to $4,585.75. As the cost of pumpage was about 4½ cents per 1,000 gallons the city will save $7,000 in one year, more than the total cost of the survey plus the repairs.—*Geo. C. Bunker.*

History of the Corrosion of the 36-inch Steel Force Main at Akron, Ohio. G. Gale Dixon. J.N.E.W.W.A., **36**: 2, 157–69, June, 1922. Instances of corrosion of steel pipe are cited. Conditions which have caused such corrosion are classified as follows: (1) Ground water corrosion, (2) Corrosive soil, (3) Rapid localized corrosion with the passage of relatively high electric current, (4) Corrosion in salt marsh, (5) "Auto electrolysis" or self-corrosion in ordinary grounds. The Akron case does not fall in any of the above classes. A 36-in. lock-bar steel force main, 11 miles long, after 5 years' service showed severe corrosion in wet clayey ground, for a distance of upwards of a mile, attributed to mild stray current found flowing on the pipe and leaving it in the corroding area at a point 3 miles from the nearest trolley tracks, to follow a route of low resistance in the natural ground, back to the equally-distant power house. A description is given of the pipe line and of the exhaustive investigations to determine the cause of corrosion, with extracts from the reports of experts.

Investigation of Electrolysis on Steel Force Main at Akron, Ohio. Victor B. Phillips. J.N.E.W.W.A., **36**: 2, 170–88. June, 1922. Following causes of corrosion were investigated, (a) Railway current, (b) Soil corrosion, (c) Small local galvanic currents. The investigations are described in detail. It was concluded that the force main is reasonably free from both soil corrosion and local galvanic action, although it was suggested that excavations be made from time to time at different points, and the pipe subjected to careful examination. The flow of current, which was considered the real cause of the corrosion, was practically eliminated by thoroughly bonding the tracks and by running out a negative feeder from the substation, thus reducing the potential drop between the force main and the substation. The author predicts that for economic reasons there will be a marked reduction in distributing distances on electric railway lines particularly the interurban ones, and that these developments will eventually eliminate electrolytic corrosion from stray currents.

In the joint discussion of this paper and the one on the same general subject by G. Gale Dixon, Theodore A. Leisen points out the almost inevitable damage that results to pipe coatings on transportation and handling, and the need of careful field painting of the abraded sections. F. A. Barbour stated that the specifications for coating the Akron force main called for a "straight-run coal tar pitch and heavy coal tar oil," but that owing to the difficulty in obtaining a coating that was not either too soft or too brittle, due to tempera-

ture variations in the pipe after preheating, the use of tar was soon given up and asphalt substituted. ALLEN HAZEN emphasized the utility of steel pipe and pointed out the advantage of encasing the pipe in concrete where there is likely to be soil corrosion, as for example in salt marshes, which can be done without excessive cost. STEPHEN H. TAYLOR, HENRY A. SYMONDS AND G. F. SEVER, also contributed experiences in the corrosion or non-corrosion of steel pipe.—*A. L. Fales.*

Electrification of Gate Valves. PAYNE DEAN. J.N.E.W.W.A., **36**: 2, 264–72, June, 1922. The advantages of electrically-operated valves are enumerated, including saving of labor and time and safeguarding of property against excessive damage from flooding due to broken mains. The Dean control system is described in detail.—*A. L. Fales.*

Some Observations on Water Consumption. CHARLES W. SHERMAN. J. N. E.W.W.A., **36**: 3, 273–78. June, 1922. Information relating to water consumption is cited, and its inadequacy as a basis for determining a reasonable allowance is pointed out. Proper provision for the future demands that serious consideration be given to this question.—*A. L. Fales.*

Can High Value Watershed Lands be Put to Profitable Use? Topical Discussion. J.N.E.W.W.A., **36**: 2, 279–87. The difficulty in utilizing watershed lands for agricultural purposes, without contaminating the water supply, was emphasized, although this is done, with certain restrictions, on the watershed of the Spring Valley Water Company of San Francisco. Instances were cited where the use of such lands for various crops, standing grass, orchards and pasturing, had not proven profitable. It was the opinion of several that the planting of conifers such as pines, which are advantageous from the water supply point of view, would prove profitable in the long run.—*A. L. Fales.*

The Design and Construction of the Gloversville Standpipe. FRANK A. MARSTON. J.N.E.W.W.A., **36**: 2, 288–306. June, 1922. Detailed description of steel standpipe 60 ft. in diameter and 55 ft. high, costing $35,015.80, including foundations, sand blasting and painting, valve chamber and piping, but excluding engineering, administration, land and fencing.—*A. L. Fales.*

Inaugural Address, Chairman, Engineering Institute of Canada, Toronto Branch. WILLIAM STORRIE. Can. Engineer, **43**: 17, October, 1922. Reference is made to the false plea of economy, so often put forward by municipalities to avoid spending money on public improvements, particularly purification of water supplies. The close relationship between the per capita expenditure on water purification in cities and towns in Province of Ontario, and typhoid fever death rate is clearly shown by figures tabulated. The amount spent per capita on water purification in Toronto has increased from 27½ cents in 1910 to $1.58 in 1921, while the corresponding typhoid fever death rate per 100,000 of population has declined from 44.2 to 3.1.—*Norman J. Howard.*

Hose Coupling Standardization. J. H. MANNING. Ohio Inspection Bureau. Can. Engineer, 43: 17, October, 1922. Attention is directed to the increasing necessity for the standardization of fire hose, hydrants and fire department fittings. Official recognition for the necessity of standardization was first given in 1891 by the National Association of Fire Engineers, the measurement of the coupling being $2\frac{1}{2}$ inches outside, $3\frac{1}{16}$ inches over the outside of the threads, and $7\frac{1}{2}$ threads to the inch. This standard was also endorsed by the A. W. W. Assoc., International Assoc. of Fire Engineers and later by the U. S. Bureau of Standards. The writer believes that in time State legislation will force standardization throughout the United States. In Ohio 6-thread fittings, within certain limits of outside diameter, which heretofore had been held to be non-convertible, could be satisfactorily recut, also fittings from $2\frac{1}{16}$ to $3\frac{5}{32}$ inches could be safely changes. While the general recutting of 6-thread towns has not yet been attempted it is stated that the work can be satisfactorily done. Undersized nipples can be brought up over desired dimensions by use of expanders and dies used in usual manner. Re-cut 6-threads have been tested with pressure up to 400 pounds and found to hold. The 8 and 7 threads, are very easily adapted, first being brought up to size by means of a drift, or expanders and the taps and dies applied in the usual manner. In Ohio out of several thousand fittings changed not a single one has been spoiled. Out of 320 waterworks in Ohio 67 are standardized and an additional 54 are being standardized, representing 35 per cent completed in number of towns. It is estimated that 80 per cent of all towns are convertible particularly in view of the great success on 6-thread fittings within the State.—*Norman J. Howard.*

Water Supplies. ALLEN W. FREEMAN. (Chapter from the Forthcoming Report of the Committee on Municipal Health Department Practice) American Journal of Public Health, 12: 759: 753, 1922. A summary of replies to questionnaires sent to eighty-three cities covering the following topics: Ownership; Control; Character of Supply; Treatment of Water; Laboratory Control and Treatment; Distribution of Public Water Supplies; Consumption of Water; and Private Water Supplies. Condensation of the report does not seem feasible. It will be worth while for those interested to look up the original article. The following extracts from the discussion may be quoted. The water supplies of 83 cities surveyed are predominantly owned by the municipalities themselves. The relationship of water supply to the health of the community using it is so direct and of such tremendous importance that it is necessary that the responsibility for the water supply be borne by the municipality. Control over the public water supply is not usually a function of the health department. It is predominantly an engineering procedure and should be, as is usually the case, a separate department of the city government. The public supplies of the 83 cities are for the most part derived from surface sources and are treated in a wide variety of ways. Chlorination as a final treatment is used in almost all the cities studied. The stored supplies of Massachusetts and a few well supplies of the middle west are almost alone in being used without chlorine. The plants are as a rule under close laboratory control. The variations in water consumption are extreme and would appear

much larger than the difference in legitimate demand would justify. Regulation of private wells and springs and of vended waters does not seem to be a practicable procedure.—*A. M. Buswell.*

55th Annual Report of the Commissioners of Water Works, Erie, Pa. 1921. 68 pp. The filter plant consists of 12 rapid sand units, each with a capacity of 2 million gallons per day when operated at a rate of 125 million gallons per acre per day. Lake Erie is the source of supply. The average daily consumption per capita during the year was 106.5 gallons, the population of the city being 110,000. The cost of collecting, purifying and pumping the water was $27.87 per million gallons, including depreciation, 232 gallons of water being pumped per pound of coal used. Complete financial operating and distribution statistics are given.—*R. E. Thompson.*

Salt Effects on the Growth of Bacillus coli in Relation to H-ion Concentrations. Jas. Sherman and Geo. Holen. Journal of Bacteriology, 7: 465, Sept. 1922. Using a 1 per cent peptone (pH 7.0) as a medium, to portions of which various neutral sodium salts having different non-metal radicals were added to obtain a 0.20 molar salt content, indicated the varying non-metal radical had a varying effect on B. coli growth. The same media containing the chlorides of ammonium, sodium and potassium produced an effect approximately the same for each, while chlorides of calcium and iron retarded greatly or inhibited growth. Using 1 per cent peptones with a sodium chloride content of 0.10, 0.20 and 0.30 molar and varying the H-ion concentrations, it appeared that optimum growth was at about the same H-ion concentration (pH 7.8) in each case, but the optimum salt concentration was found to be 0.20 molar for the various H-ion concentrations. With 0.20 molar sodium chloride concentration, there is very little difference in the rate of growth of B. coli over a wide range of H-ion concentration (pH 5.3 to 8.3) while in 1 per cent peptone alone the range is much narrower (pH 7.0 to 8.3). At pH 4.8 B. coli would rarely grow in 1 per cent peptone, but grew readily in the media of 0.20 molar NaCl content. The NaCl effect of extended "pH limit of growth" is not general for all bacteria tried but is true of B. coli and B. alkaligenes. Sodium citrate in the same concentration as the NaCl had a narrowing effect on the "pH limit of growth" of B. coli and is even more narrow than that of pure 1 per cent peptone. The rates of growth were in every case determined by the time that expired between inoculation and the first sign of turbidity of the medium. The various effects are illustrated graphically by the authors. —*Linn H. Enslow.*

Chemistry of Sanitation. A. M. Buswell. Jour. Ind. & Eng. Chem., 14: 840, Sept. 1922. A comprehensive review of the work in the field of chemistry which has been published in recent years on the various phases of water-analysis, water and sewage-purification and stream pollution. Although the chemical test to determine the sanitary quality of waters has lost its former significance the need for improvement in water purification exists and a large field yet remains for the chemist to explore in this matter. The matter reviewed on *Water-Purification* covers the following: Relation of pH to precipi-

tation of hydroxide of alumina and also the colloidal-phase in the coagulation and precipitation of aluminum hydroxide in water-purification. The corrosion of mains, etc. caused by "aggressivity" of the water, due to a certain form of carbon-dioxide in the presence of dissolved oxygen. Means of reducing "aggressivity" are given and methods of removing the oxygen or the "aggressive" form of the CO_2 are outlined. The adsorption of ammoniun salts by filter-beds and shrinkage of filter-beds caused by adsorption. Taste and odor troubles caused by trade-wastes, algae or chlorine in the form of hypochlorous acid or organic combination and the means of their elimination. The efficiency of sterilization by chlorine or hypochlorites with the minimum occurrence of tastes and odors is made possible through chlorine control by the "absorbed-residual" chlorine test. The investigation of the nitrogen cycle in water, modification of the hardness test, etc. The Zeolite base exchange in water softening. Mention is made of the expected printing of the revised edition of the A.P.H.A. Standard Methods as improved through coöperation of the A.P.H.A., the A.W.W.A. and the A.C.S. The matter reviewed on *Stream Pollution* and *Sewage Disposal* covers the following: The relation of various industrial wastes to water supplies. The limit of salt content in a potable water. The oxygen requirement of polluted waters and the conditions necessary for its provision. The purification of sewage with reference to colloid chemistry *vs.* the biochemical theory. The latest approved test to determine the "biochemical oxygen demand" for sewages and polluted waters is described in detail and commented upon. Note: This method will appear in the new standard methods of the A.P.H.A. It appears that the determination of the 5-day "oxygen demand" and suspended matter are the two most satisfactory tests for determinng sewage-plant efficiency. Attention is directed to the advantages of the ultra-filter over the Gooch crucible method for determination of suspended matter. Literature is mentioned covering the various methods for estimating colloids. Among them is suggested use of the nephelometer. A comprehensive and valuable Bibliography is included at the end of this timely review.—*Linn H. Enslow.*

Adsorption a Criterion of Corrosion. B. D. Saklatwalla. Chemical and Metallurgical Engineering, **27**: 13, 647, September 27, 1922. The author suggests that a possible reason why some metals corrode at a rapid rate while others corrode very slowly is due to the power of adsorbing gases. Most of the so-called noble metals take up large volumes of gases, which are occluded not only in the pores of the metal in a loose condition, as platinum sponge, but are adsorbed on the surface and sometimes dissolved in the metal, forming a solution. It appears that every solid body in contact with a gas has the capability of condensing the gas on its surface. This condensation, in certain cases, reaches a magnitude corresponding to a pressure of several thousand atmospheres. If a body has a high degree of adsorption, the condensation and consequent interaction velocity will be great and hence surface oxidation of the solid will take place quickly, possibly instantaneously. If this surface film has the necessary physical qualities of homogeneity, correct thermal expansion, and so on, it will prevent or slow up the velocity of further interaction. The author concludes if these contentions can be proven correct, we

might have at command a simple and quick method of judging the adaptability of alloys and metals for corrosion. The method would be applicable as a criterion for atmospheric as well as submerged corrosion.—*John R. Baylis.*

Fundamental Physical and Chemical Properties of Commercial Lime—The Available Lime Content. M. L. HOLMES AND G. J. FINK. Chemical and Metallurgical Engineering, **27**: 8, 347–9, August 23, 1922. The National Lime Association has under way an extensive investigation in which limes from every section of the country are being studied for the purpose of obtaining comparative data on all the important characteristics. The method of sampling and preparation of samples for analyses is given. For determining available lime, the Bureau of Standards Modification of the Scaife method was used. The authors show that calcium limes have a higher available lime content than magnesium limes, and that quicklimes usually have a higher available lime content than the corresponding hydrates.—*John R. Baylis.*

Typhoid Fever Held Compensable under Workmen's Compensation Act. Public Health Reports, **37**: 10, 538, March 10, 1922. Typhoid fever when contracted by employee through drinking impure water furnished by the employer is declared by the Appellate Court of Indiana to be an injury and compensable under the Workmen's Compensation Act.—*Sol Pincus.*

Term "Injury" in Ohio Workmen's Compensation Law Construed. Public Health Reports, **37**: 42, 2646, October 20, 1922. The Ohio Supreme Court reverses decision of lower court in a case of a typhoid fever death, and decides diseases contracted in the course of employment are not included in term "injury" of Workmen's Compensation Act. Distinguishes, however, between diseases contracted in the course of employment, which are excluded from the term "injury," and diseases which are occasioned or follow as a result of some physical injury, which apparently are not excluded as being compensable. —*Sol Pincus.*

Ohio Law for Enforcing Correction of Stream Pollution and Improvement of Public Water Supplies. The Ohio law is about the most advanced legislation of any State concerning water supply and sewage matters. Provision is made for investigation of water supply and sewage conditions and authority furnished for the issuance of orders by the State Commissioner of Health requiring water supply or sewage installations or improved operation or changes in existing structures. Hearings on such public improvements are to be held before the State Public Health Council. The findings or orders of the Commissioner of Health may be submitted upon demand by the local or company officials to two sanitary engineer referrees who if necessary are to choose a third sanitary engineer referee, who may modify or alter the orders. Appeals from findings of the State Health Commissioner other than to referrees can be made only to the State Supreme Court. The important provision is included for exempting bonds issued by a municipality to provide funds for the carrying out of the orders of the Commissioner of Health from the other legal restrictions on the debt limit of the municipality, such bonds not to exceed 3 per cent of the total value of all property in the city.

The members of the local council or department, or officers of a private company are made personally liable for any default in carrying out the orders and are subject to a fine of $500.—*Sol Pincus.*

Quarantine of Typhoid Carrier Upheld. Public Health Reports, **37**: 21, 1253–9, May 26, 1922. The Supreme Court of Illinois decided that, when a quarantine is established by a duly authorized board of health, it is legal even for typhoid bacilli carrier though the carrier may not herself be sick. The right is upheld to establish reasonable quarantine regulations for the person as long as she is discharging the germs of a contagious and infectious disease. —*Sol Pincus.*

Lessons from Recent Statistics of Typhoid Fever. Ohio's Health, **13**: 2 & 3, 46, Mar. 1922. Typhoid fever statistics of the Metropolitan Life Insurance Co. do not show a marked improvement in 1921 over 1920. Droughts, general in 1921, depleted water supplies and it is suggested that recourse to impure auxiliary supplies was a contributing factor in maintaining the typhoid death rate. The article also suggests the wisdom of emergency chlorination of such auxiliary supplies.—*E. S. Chase.*

The Gouverneur Typhoid Outbreak. Health News, N. Y. State Dept. Health, **17**: 2, 51, Mar. 1922. An account of an outbreak of 58 cases of typhoid in a village of about 4000 inhabitants, due to an infection of a private well. The village is provided with a public water supply which is polluted by sewage and industrial wastes and, although chlorinated, is unpalatable, a condition which led many to use local wells giving water more pleasing to the senses. An example of the necessity of public water supplies being attractive physically as well as safe bacterially.—*E. S. Chase.*

Typhoid Problems in Illinois. S. S. Winner. Ill. Health News, **8**: 7, 191, July, 1922. Cites an outbreak of typhoid in an Illinois city of 30,000 population due to an infection of the city water supply through a cross-connection with a polluted industrial supply. The outbreak of typhoid was preceded some weeks by an outbreak of diarrhoea in the industrial establishment. —*E. S. Chase.*

Good Advice the Keynote of Success in Wheeling's Water Supply Campaign. E. S. Tisdale. Quart. Bull. W. Va. State Dept. Health, **9**: 3,102. July, 1922. An account of an educational campaign carried out by the State Health Dept. for the improvement of the water supply of Wheeling. Chlorination first secured, and then, filtration, in spite of considerable local opposition to mechanical filters. A financial loss of $1,356,000 is estimated as due to excessive typhoid in Wheeling over the ten year period, 1910–1920.—*E. S. Chase.*

Report of Sanitary Engineering Division. Report of Va. State Board of Health for year ending Sept. 30, 1921, p. 75. This report details the work of the Division in protecting water supplies and describes several water supplies of Virginia. No typhoid outbreaks attributed to water supplies occurred

during the year. Approximately one-third of the population of the state, or 700,000, supplied by public water supplies. The supplies are inspected by the division, regular reports are received from water works and samples are collected for bacterial analysis. A list of municipal water supplies in the state is given together with data relative to source, treatment and results of analyses for B. coli.—*E. S. Chase.*

Making Chlorine at the Point of Consumption. C. W. MARSH. Jour. N. E. W. W. Assoc., **36**: 1, 1, March 1922. A description of a new type of electrolytic cell for the production of chlorine gas for water or sewage disinfection at the point of use. The cell is approximately 2.5 ft. long, 10 in. wide and 2.5 ft. high and consists of a concrete top to which are attached steel plates carrying in turn asbestos paper, the plates being the cathodes and the asbestos the diaphragm. Graphite anodes are suspended from the top and are enclosed by steel plates forming the compartment which holds the brine solution. In addition there are fittings of various sorts. The chlorine outlet leads from the top. Chlorine is produced in proportion to the amount of current used and can be applied to the water by water injectors and can be controlled automatically. The author gives cost figures,—*E. S. Chase.*

Notes on Meters for Town Water Distribution. G. S. BURT ANDREWS. Surveyor, **62**: 1590, 9, July 7, 1922. Entire supply of Johannesburg is metered. Tests show all small meters run slow.—*A. W. Blohm (Courtesy I.W.M.).*

Pumping and Filter Plant at Sturgeon Falls, Ontario. ANON. Canadian Eng., **42**: 24, 599, June 13, 1922. Three pressure filters, with alum, produce water of such quality that chlorination is unnecessary. Filters and accessories, to supply town of 4,000 people, cost $9,000.—*A. W. Blohm (Courtesy I.W.M.).*

Cardiff Waterworks. C. H. PRIESTLY. Surveyor, **62**: 1590, 7, July 7, 1922. Roughing filters being constructed to obviate incrustation of conduits, and partially to purify water delivered to storage reservoirs near city.—*A. W. Blohm (Courtesy I.W.M.).*

The Water Supply of the Border Cities. ANON. Contract Record, **36**: 30, 731, July 26, 1922. Representatives from several Canadian border cities recommend construction of filtration plant and pumping station to deliver water to suction wells of existing companies. Existing companies to continue control of rates, collections, etc., until expiration of lease.—*A. W. Blohm (Courtesy I.W.M.).*

Dangers of Household Filters. M. W. COWLES. Sanit. Eng. Lab., Illinois Dept. of Health. Health, **2**: 5, 27, May 1922. Most satisfactory solution to household filter problem is a satisfactory public water supply.—*A. W. Blohm (Courtesy I.W.M.).*

Water Supply Installations for Farmsteads and Country Estates. WILLIAM P. GERHARD. 1922. Sources of supply, methods of pumping, storage facilities and piping arrangements for farmsteads and country estates are discussed. —*A. W. Blohm.*

Purification of the Water Supply of Avignon (France). **Ozone.** MARCEL PAILLET. L'Ingenieur-Constructeur, Sept.-Oct., 1921; Le Genie Civil p. 597, (Dec. 31, 1921); Bul. internat. office d'hyg. publ., 14, 1125, (1922.) A contaminated ground water was successfully treated by ozone at an estimated net cost for the treatment of 4 francs per 1000 cubic meters, or about $1.20 per million gallons (U. S.) with the franc at 8 cents.—*Jack J. Hinman, Jr.*

A Little Book on Water Supply. WILLIAM GARNETT. University Press, Cambridge, England, 1922, pp. xv plus 144, 8vo, 7 shillings post free. An elementary book on water supply intended chiefly for the citizens of London. Short descriptions of the water supplies of New York, Jerusalem, Manchester, Glasgow, Liverpool, Birmingham, and much fuller description of the supply furnished London through the Metropolitan Water Board.—*Jack J. Hinman, Jr.*

The Sangamon River Dam at Decatur, Illinois. J. ALBERT HOLMES. Proc. Ills. Soc. Engrs. 37, 41, (1922). An eng. description of dam to store 8 billion gallons for Decatur water supply. Watershed above dam 862 sq. mi. Length of dam 1770 ft.—*Jack J. Hinman, Jr.*

Storm Water Run-Off in Cities. CHAS. B. BURDICK. Proc. Iowa Eng. Soc., 37: 44, 1922. Calculations of run-off for design of sewer systems have been empirically handled. Thus calculations for Baltimore are about 10 times those for Gary. A hitherto unpublished table summarizing data on storms which had a rate at least equal to 0.74 inches per hour is prepared for 23 cities of U. S. east of Mississippi from data of the U. S. Housing Commission, 1918 —*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Egyptian Ophthalmia (Trachoma) and Public Swimming Pools. Gesundheits Ingenieur, 260, (May 20, 1922); Bul. office internat. d hyg. publ., 14, 973, (Aug. 1922.) Granular conjunctivitis was observed in young men who frequented swimming pools at Cologne, Berlin and Neukolln. At latter place the installation of liq. Cl. apparatus has given good results and it is proposed to install apparatus at pool at Friedrichshain at cost of 50,000 M.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Illinois Central Improves its Water Supply in Coal Fields. C. R. KNOWLES. Ry. Main. Engr. 18, 300, 1922. Effects of summer droughts in southern Illinois coal fields have caused serious water shortage and serious pollution of surface supplies by acid drainage from mines. This has been largely overcome by installations of reservoirs. Plans and costs are given.—*R. C. Bardwell.* (*Courtesy Chem. Absts.*).

Useful Pipe Chart. W. F. SHAPHURST. Power Plant. Eng. 24: 621–12, 1922. Chart correlating size of pipe, velocity in ft. per sec., quantity in cu. ft. per min., gal. per min. and lbs. per min., based on formula $Q = 2.45\ d^2\ V$, for gal. per min., $Q = 0.37\ d^2\ V$ for cu. ft. per min. and $Q = 20.4\ d^2\ V$ for lbs. per min.—*R. C. Bardwell* (*Courtesy Chem. Abst.*).

A Lime, Soda Ash Chart. F. D. YEATON. Ry. Main. Engr. **18:** 169–5, 1922. Chart gives pounds Na_2CO_3 and $Ca(OH)_2$ per 1000 gal. water for varying amounts of hypothetical combination of incrusting salt shown as gr. per gal. —*R. C. Bardwell (Courtesy Chem. Abst.).*

Fifth Omaha Reservoir Embodies New Principles in Design. Mun. Cty. Eng. **62:** 179–80, 1922. The reservoir is lined with a flexible reinforced concrete blanket 6 inches thick. The steel is 0.4 of 1 per cent of cross section each way. The concrete is 1 cement to 3 sand-gravel.—*Langdon Pearse.*

Rearranging the Park Ridge Pumping Station. W. T. MCCLENEHAN. Mun. Cty. Eng. **62:** 180–2, 1922. Details the rearrangement of an electrically operated pumping station for convenient and easy operation.—*Langdon Pearse.*

Water Works Reconstruction at Rockford, Ill. R. C. WILSON. Ill. Sect. Am. W. W. Assn. 1922; Mun. Cty. Eng. 62; 182–4, 1922. A new 5 mil. gal. reservoir has been built, 4 wells provided (15 in. casing to 110 ft. depth, first 300 ft. 14 in., then 12 in. to 1600 ft.) of estimated capacity 2 mil. gal. per 24 hr., a new pumping station and boiler room with automatic stokers. The cost will be about $750,000.—*Langdon Pearse.*

Pine Hill Dam. Pub. Works, **52:** 397–9, 1922. This concrete dam is 1000 ft. long, 113 ft. high at Worcester, Mass. Masonry is cyclopean. Construction joints have ingot iron stop plates 12 x ½ in.—*Langdon Pearse.*

Water Works Services. Pub. Works, **53:** 50–1, 69–73, 1922. Statistical data on various cities.—*Langdon Pearse.*

Domestic Water Wastes in England. G. R. COLLISON. The Surveyor; Eng. Contrg., **58:** 206–7, 1922. The normal consumption is way below American standards ranging from 14 to 25 gal. per capita per 24 hr.—*Langdon Pearse.*

Steel Water Mains in New Bedford. Report New Bedford Water Board, 1921; Pub. Works, **53:** 165, 1922. Eng. Contrg., **57:** 565, 1922. Thirty-six inch steel pipe main, 22 years old, shows pitting $\frac{1}{64}$ to $\frac{1}{8}$ inch deep.—*Langdon Pearse.*

Town and Regional Planning in Relation to Sanitation. R. O. WYNNE ROBERTS. Can. Engr., **43:** 371–4, 1922.—*Langdon Pearse.*

Laying 186 ft. of 48-inch Cast Iron Pipe per Day for Chicago Gas Co. Mun. Cty. Eng., **43:** 101–3, 1922. Eng. Contrg., **58:** 245–6, 1922. The trench (7 x 7 ft.) is dug by Austin excavator, sometimes 408 ft. per day, average 204 ft. Excavation runs 2 cu. yd. per lin. ft. Pipe is laid by gasoline crane mounted on tractor. Joints calked by air hammer, by 2 men at each joint. Two men average 2 joints per day. Pipe laying avg. 186 ft. per day.—*Langdon Pearse.*

Water Works System at Richmond, Ont. G. H. BAKER. Can. Engr., 42: 437–9 (1922). At a cost of $90,287 a water works system has been installed including repairs to an old dam, making an 8 mil. gal. reservoir, coagulation basin, filter, pumps and tank.—*Langdon Pearse.*

A Buffer Solution for Colorimetric Comparison. T. C. MCILVAINE. J. Biol. Chem., 49: 183–6, 1921. From Chem. Abst. 16: 729, March 10, 1922. The system requires but two stock solutions and covers a range from pH 2.2 to 8.0, which approximately includes the limits for physiological media. The solutions employed are 0.2 molar disodium hydrogen phosphate and 0.1 molar citric acid.—*R. E. Thompson.*

A Method of Determining Hydrogen-Ion Concentration and the Relationship between pH and Acid Taste. P. HAMPSHIRE. Bull. Bur. Bio-Technology, No. 3, 55–56, 1921. From Chem. Abst. 16: 729, March 10, 1922. A description of the methods of Medalia (C.A. 15, 244) and Gillespie (C.A.14, 1499). An attempt is made to correlate the acid taste and pH in the case of beers.—*R. E. Thompson.*

Bacterial Cataphoresis. ERICH PUTTER. Z. Immunität., 32: 538–57, 1921. From Chem. Abst. 16: 730, March 10, 1922. A group of bacteria was studied by means of the microscopic method of cataphoresis. They all showed a definite negativity with practically no tendency to change. They lose their charge in strong acid and to trivalent cations. The addition of peptone makes the bacteria unchangeable in acid solution. In this respect they behave like kaolin. Of the elemental structures of higher organisms only the cell nuclei have the same electric properties as bacteria.—*R. E. Thompson.*

Dissolved Gases in Water Supplies. ANON. Chem. Age (London), 5, 694–5, 1921. From Chem. Abst. 16: 772, March 10, 1922. Factors influencing the amounts of nitrogen, oxygen and carbon dioxide contained in natural water supplies and methods employed for determining the quantities are given. The nitrogen cycle is discussed.—*R. E. Thompson.*

Active Carbonic Acid and the Hydrogen-Ion Concentration in Water Investigation. J. TILLMANS. Z. Nahr. Genussm., 42, 98–104, 1921. From Chem. Abst. 16: 773, March 10. 1922. A reply to critical articles by J. M. KOLTHOFF (C. A. 15, 3703, 3353). A variation in the (solubility) product of calcium carbonate from that found by other authors is explained by the variation in the size of the powdered marble used in the determinations. The application of the system $Ca(HCO_3)_2$–CO_2 to natural waters is defended by experimental and industrial results.—*R. E. Thompson.*

Bacteriologic Tests of Drinking Water. J. M. MESA. Rev. assoc. med. Argentina, 35, 639 (1921); J. Am. Med. Assoc., 77: 1930, 1921; Public Health Eng. Abst. Dec. 31, 1921. From Chem. Abst. 16: 774, March 10, 1922. Gas formation is estimated by means of an inverted hemolysis tube containing a culture medium consisting of a 40 per 1000 solution of peptone to which lactose and

neutral red have been added. The presence of the colon bacillus is indicated by change of tint, fluorescence and production of gas in 24 hours.—*R. E. Thompson.*

New Type of Mineral Waters: Nitrate Waters. C. LEPIERRE. Compt. rend., 173, 783–6, 1921. From Chem. Abst. **16**: 774, March 10, 1922. A water obtained at a depth of 15 m. within 50 m. of the ocean at Ericeria, Portugal, is discussed. The water contained 3.7999 g. per liter of total solids, consisting approximately of 64 per cent chlorides, 18.8 per cent nitrates, 11 per cent bicarbonates and 8 per cent sulphates, and had a nitrate content of 0.686 g. per liter.—*R. E. Thompson.*

Sewage Disposal in the Chemical Industries. H. BACHS. Z. angew. Chem., **34**: Aufsatzteil, 561–3, 1921. From Chem. Abst. **16**: 775, March 10, 1922. The applicability of general sewage disposal methods (dilution, mixing with municipal sewage, trickling filtration, partial purification, etc.) to chemical industrial wastes is discussed in detail.—*R. E. Thompson.*

Water Supplies and Drinking Devices. F. R. KING AND W. D. STOVALL. Domestic Eng., **97**: 483–5, 1921. Public Health Eng. Abst., Jan. 14, 1922. From Chem. Abst. **16**: 777, March 10, 1922. The transmission of pathogenic bacteria by bubbling fountains and other drinking devices is discussed.—*R. E. Thompson.*

Swimming Pool Sanitation. G. M. FAIR. Intern. J. Public Health., **2**: 631–6, 1921. Public Health Eng. Abst. Jan 21, 1922. From Chem. Abst. **16**: 777, March 10, 1922. F. summarizes the hygienic aspects, management, and treatment of swimming pool waters, features of construction and sanitary control of pools.—*R. E. Thompson.*

Dispersion of Water in the Ultra-Violet. J. DUCLAUX AND P. JEANTET. J. phys. radium, **2**: 346–50, 1921. From Chem. Abst., **16**: 874, March 20, 1922. The dispersion of water in the ultra-violet is very great, although it is rather small in the visible region. Between 1990 and 1862 A. the dispersion is nearly 20 per cent larger than that of silicon dioxide and more than twice that of calcium fluoride.—*R. E. Thompson.*

The Differentiation of Boiled and Unboiled Water. W. R. G. ATKINS. Nature, 108, 339, 1921. From Chem. Abst., **16**: 978, March 20, 1922. As boiling always lowers the H-ion concentration of water by removing the carbon dioxide from solution and decomposing carbonates, boiled and unboiled water can be differentiated by means of indicators appropriate to the type of water. Thus, a soft tap water which had a normal pH value of 6.8 and gave a yellowish color with phenol red, on boiling developed a full red with this reagent, a light pink with phenolphthalein and a yellow color with thymol blue; pH then equalled 8.5. (This test would necessarily be applied soon after boiling, and before equilibrium with the atmosphere had been regained.—(Abst.) —*R. E. Thompson.*

Dissolved Oxygen in Waters. REINALDO VANOSSI. Anales asoc. quim. Argentina, 9: 235–45, 1921. From Chem. Abst., 16: 979, March 20, 1922. A general discussion. A determination of the dissolved oxygen content of a fresh sample is no test for the degree of pollution. It is recommended that the sample be diluted with several volumes of distilled water containing oxygen and incubated for 5–15 days, the dissolved oxygen being determined at intervals of 2–3 days. See C. A. 15, 3703.—*R. E. Thompson.*

Treatment of Water for Steam Making. J. S. SIMSOHN. Chem. Age. (N.Y.), 30: 43–6, 1922. From Chem. Abst., 18: 979, March 20, 1922. General principles of water softening by the lime-soda and zeolite processes are outlined. Corrosion of boilers may be due to free or half-bound carbon dioxide, oxygen or soluble salts which decompose, producing acids. Under high temperatures and concentrations sodium carbonate decomposes, producing sodium hydroxide and sodium formate (or salts of other organic acids,) both of which may be injurious. Zeolite softened water gives a higher sodium carbonate content, and the boiler water should be tested at frequent intervals to determine its concentration. The presence of other salts influences the decomposition of the sodium carbonate.—*R. E. Thompson.*

The Removal of Oil from Condenser Water by Electrolysis. F. HOYER. Feuerungstechnik, 10: 33–34, 1921. From Chem. Abst., 16: 979, March 20, 1922. After the addition of a little ordinary water to increase the conductivity, the hot condenser water is passed between iron electrodes and direct current passed through it. The emulsified oil coagulates and can be easily filtered off. The cost is small.—*R. E. Thompson.*

Bacillus Welchii in a Public Water Supply. H. B. LARNER. J. Am. Med. Assoc., 78: 276–9, 1922. From Chem. Abst., 16: 980, March 20, 1922. The possible cause of intestinal disturbances by B. Welchii is discussed, and epidemics at Montclair, N. J., are referred to. Larner suggest the possible need of extending the methods of water analysis to include the detection of B. Welchii.—*R. E. Thompson.*